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## WITH ABSTRACT OF THE LITERATURE

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**Studies in Dust Retention: III. Factors Involved in the Retention of Inhaled Dusts and Fumes by Man**

**Hypertension in Industry**

**Injuries Produced in the Organism by the Discharge from an Impulse Generator**

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respiration rate will be noted. In the case of breathing while inhaling carbon dioxide, the degree of scattering is least and the respiration rate most regular; in breathing during exercise, scattering is greatest and the respiration rate most irregular; the scattering, as well as the respiration rate, is about the same in both normal breathing and resting mouth breathing.

The data for all breathing conditions shown in Figure 1 have been classified according to respiration rate, and the retention values for constant rates of respiration are plotted in Figure 3. The lines of best fit through the points

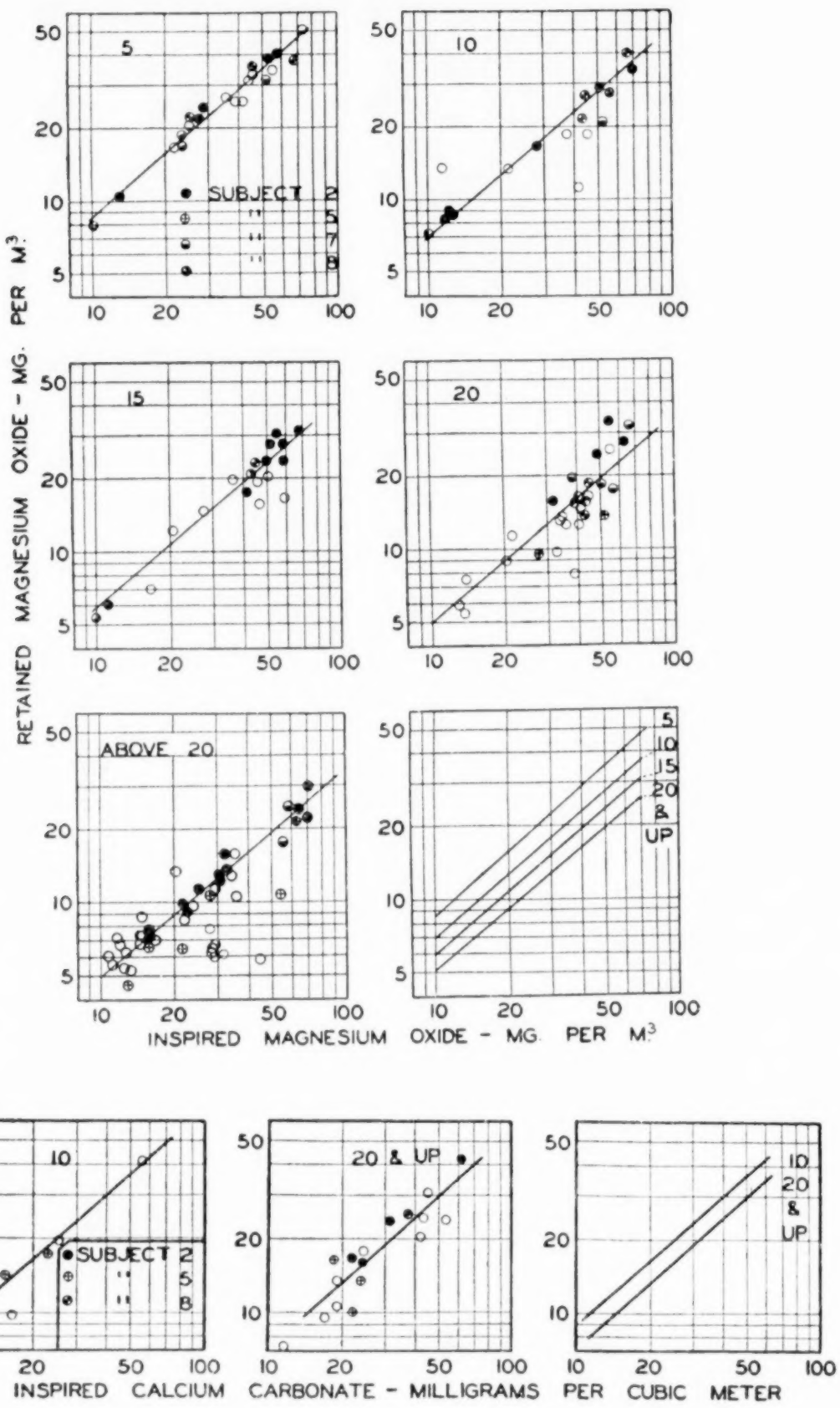


FIG. 3.—Retention of magnesium oxide and calcium carbonate at different respiration rates.

have also been transferred to one graph for comparison. Percentage retention values for four different dust concentrations, calculated from these lines, are plotted against respirations per minute in Figure 4. In Figure 5, percentage retention is shown plotted against inspired dust concentration for various constant rates of respiration.

According to Figure 4, percentage retention is inversely proportional to the respiration rate for rates below 20 per minute. This may be explained by the fact that as the respiration rate falls, the air velocity in the respiratory system decreases, thus increasing the opportunity for dust removal by settlement. At rates above 20 respirations per minute settlement is prob-

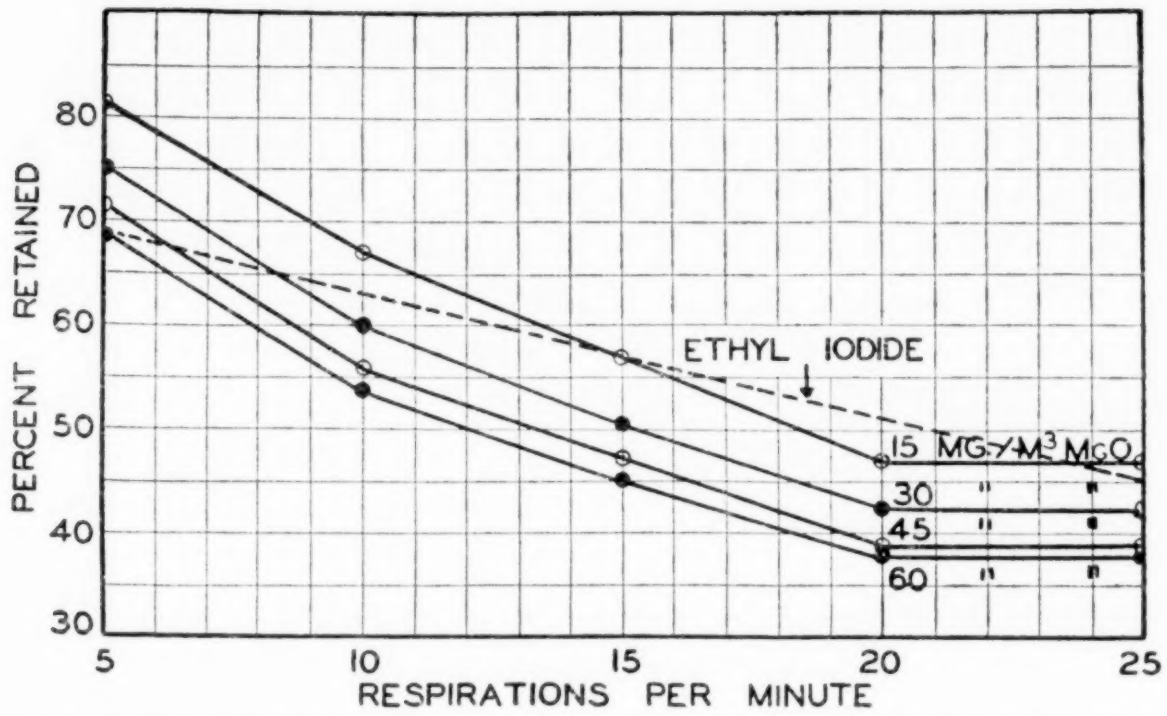


FIG. 4.—Variation in percentage retention of magnesium oxide and ethyl iodide (2) with respiration rate.

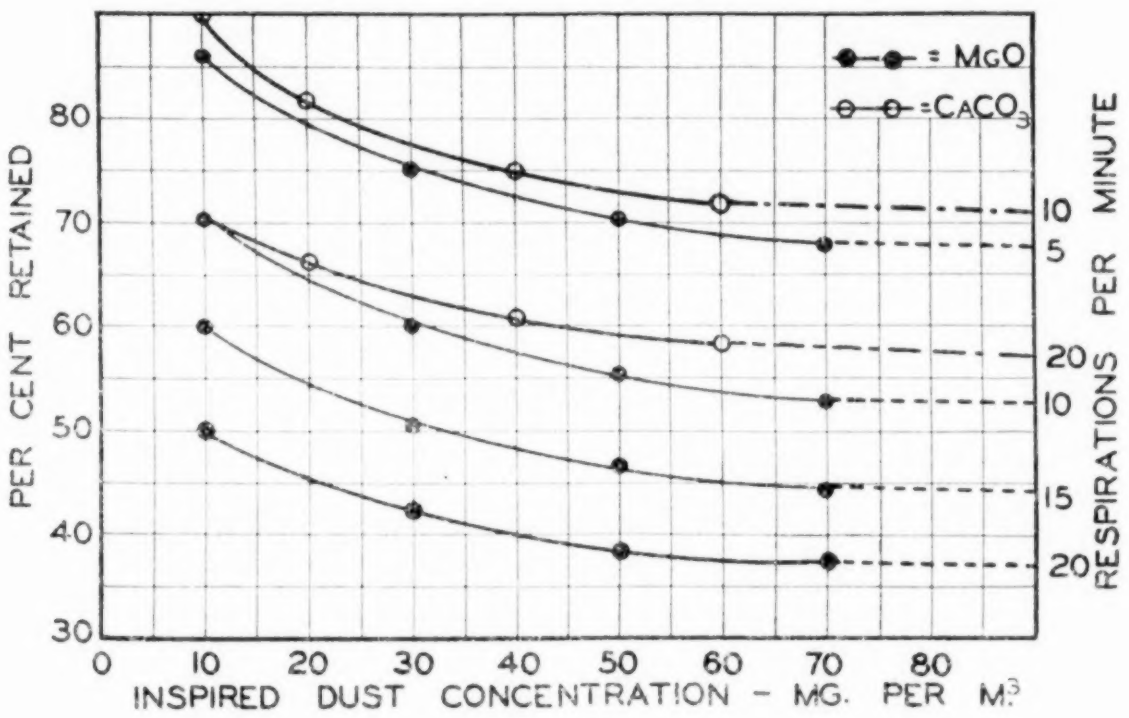


FIG. 5.—Average percentage of magnesium oxide and calcium carbonate retained by subjects breathing at respiration rates indicated. Lines were calculated from those in Figure 3.

ably negligible because of the short time each breath remains in the respiratory system.

Blumgart, Gilligan, and Swartz (2), in the study of the elimination of inhaled ethyl iodide vapor, also found that retention was inversely proportional to respiration rate (Fig. 4), although their results present a linear rather than a curved relationship as indicated for magnesium oxide and calcium carbonate. Decrease in the time for absorption of the ethyl iodide in the blood with an increase in respiration rate would also explain their results.

That respiration rate should be taken into consideration in dust retention studies is evident from Figure 5. Drinker, Thomson, and Finn (3) are the only investigators who have given the respiration rate in their published data; but even they did not study the relation of this factor to retention. They found that zinc oxide, both freshly formed and in the form of a powder (Kadox), and calcium carbonate were retained to the extent of 55 per cent. at concentrations of from 50 to 450 mg. per cubic meter. The median respiration rate in their experiments on freshly formed zinc oxide was 10 per minute; on Kadox 11 per minute; and on calcium carbonate 12 per minute. Percentage retention for magnesium oxide, which is similar to zinc oxide in physical properties, at 10 respirations per minute and at a concentration of 50 mg. per cubic meter is shown (Fig. 5) to be approximately 55 per cent.; this is in agreement with the work of Drinker, Thomson, and Finn. The percentage retention of calcium carbonate,[1] under the same conditions (12 respirations per minute and 50 mg. per cubic meter), was found, however, to be 70 per cent. (Fig. 5) instead of 55 per cent., the value obtained by these investigators. The reason for this difference is not apparent. Notwithstanding the fact that the results on calcium carbonate from the two studies cannot be reconciled, it is probable that many of the contradictory results on dust retention in the literature can be explained by differences in the respiratory rates of the two subjects. Drinker, Thomson, and Finn's results on zinc oxide are a typical example.

*Volume per Respiration.*—Volume per respiration was calculated from the minute-volume[2] of air breathed and the respirations per minute. The retention values for magnesium oxide were classified according to the volume per respiration, and the results are plotted in Figure 6. When the lines of best fit through the points were transferred to one graph (Fig. 6, No. 6), they were found practically to coincide, indicating that retention is not affected by changes in volume per respiration over the range from 300 to 1,300 c.c. This range of volume per respiration covers all conditions studied except that of having the subjects breathe at the rate of 5 times per minute, which is considerably subnormal.

In the analysis given above, the respiration rate, which has just been shown to be so important in dust retention, was not taken into considera-

[1] From the same source as that used by Drinker, Thomson, and Finn.

[2] Corrected to 21°C. and 760 mm.

tion other than to assume that its frequency distribution was the same for the different group values of volume per respiration. In order to determine the effect of volume per respiration alone upon percentage retention, it was necessary to remove the influence of respiration rate and concentration of inspired dust. This was done in the following manner: The median values of the percentage retention of magnesium oxide for constant rates of respiration and for concentrations of inspired dust above 40 mg. per cubic meter were plotted against the corresponding values of volume per respiration. Only those determinations for which the inspired dust concentration was above 40 mg. per cubic meter were used, since it has been shown (1) that percentage retention does not change appreciably with an increase in dust concentration above that value (see also Fig. 5). The

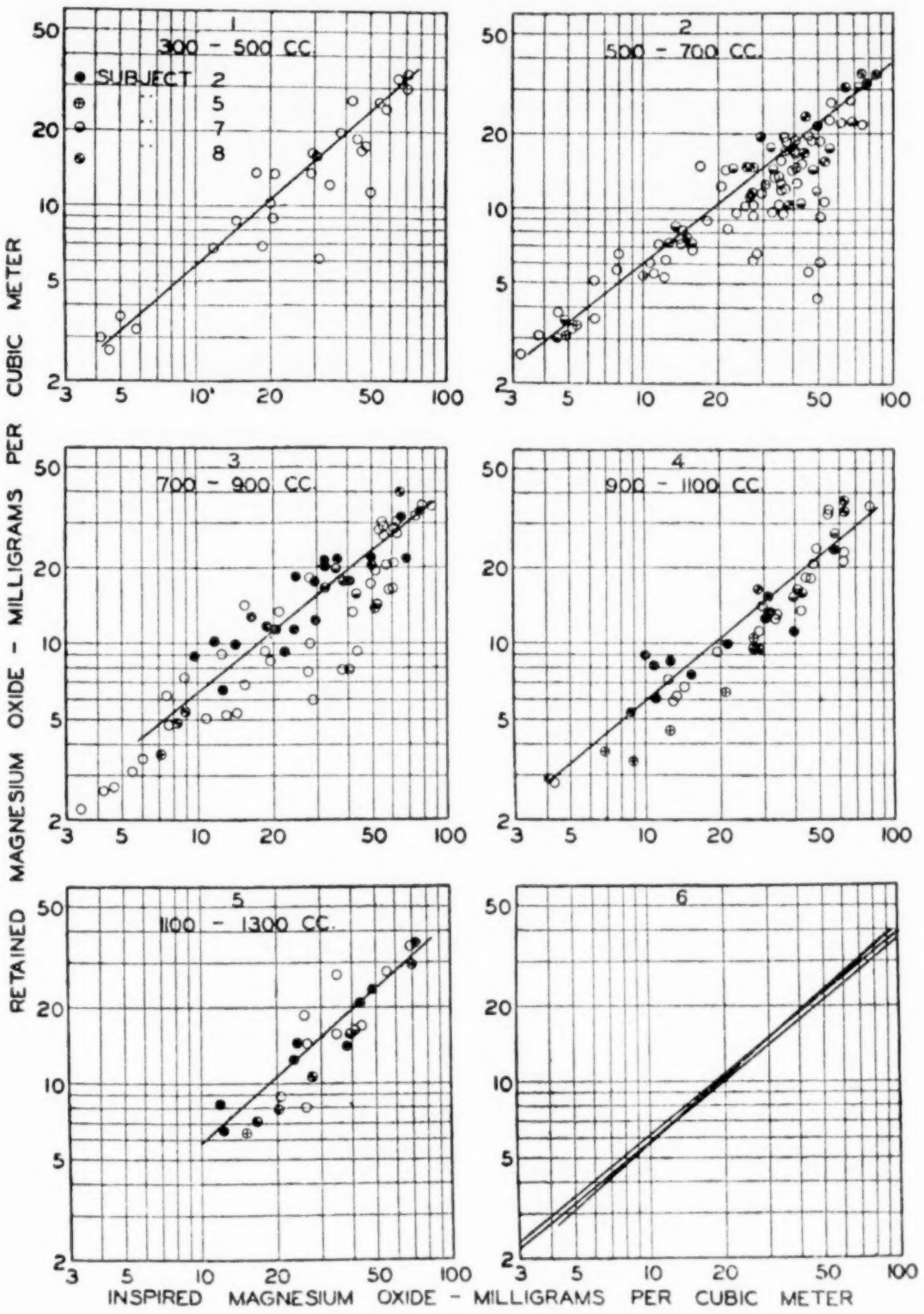


FIG. 6.—Magnesium oxide retained at various volumes per respiration.

results are plotted in Figure 7 and indicate rather clearly that the volume per respiration, or the size of the breath, has little if any effect on the percentage of inspired dust retained.

Although a definite explanation for these results is lacking, they may be substantiated, in part, by certain considerations of the mechanism of respiration. The tidal air may be divided into two parts: the alveolar portion and the air in the dead space. The alveolar air enters the lungs first and leaves last; it comes in contact with a relatively great area of moist surfaces; it is subject to diffusion into relatively clean air already present in the alveolar region; and it remains in the respiratory system the longest period of time. In view of these facts, it may be assumed that the dust contained in this portion of the tidal air is almost completely removed. Since the air in the dead space enters the lungs last and leaves first, it has little opportunity to adhere to moist surfaces or to become diffused, and therefore its dust content is probably relatively unchanged. The proportion of the air in the dead space to alveolar air in tidal air remains practically constant at 1 to 2, regardless of the size of the breath (4), so that it is reasonable to suppose that changes in the volume per respiration have little if any effect on the percentage of dust retained.

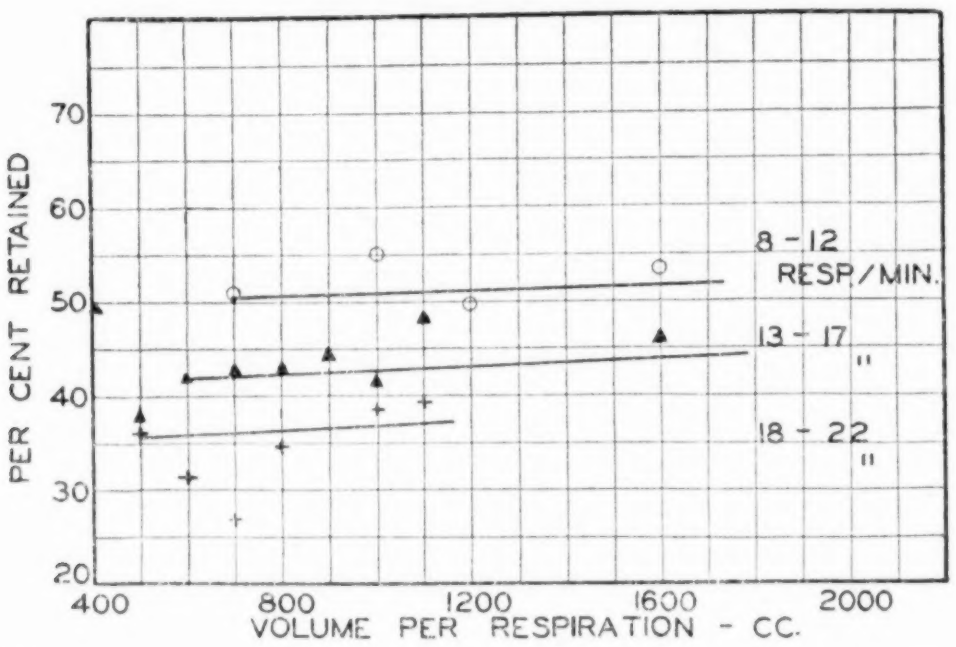


FIG. 7.—Variation in percentage retention with volume per respiration at fixed ranges of respiration rate for all subjects breathing magnesium oxide at an inspired dust concentration of 40 mg. or more per cubic meter. Points shown are median values.

*Minute-Volume.*—Minute-volume was obtained by dividing the total volume[3] of air breathed by the number of minutes in a breathing period, and is equivalent to the product of respirations per minute and volume per respiration.

Variation in minute-volume was secured by having the subject exercise (mark time or pedal an unloaded bicycle ergometer) and also by having him inhale approximately 5 per cent. carbon dioxide. The former caused an increase of approximately 50 per cent. over normal minute-volume, whereas the latter caused an increase of about 100 per cent.

Variation in the retention of inhaled

[3] Corrected to 21°C. and 760 mm.

magnesium oxide with variation in minute-volume is shown in Figure 8. A comparison of the retention curves for the various group values of minute-volume shown in graph 9 of Figure 8 indicates that retention is inversely proportional to the minute-volume, although the tendency is not marked.

bear a direct relation to minute-volume. Dust retention was found to be inversely proportional to the respiration rate and not to be affected by the volume per respiration. Hence, it may be argued that the slight correlation between retention and minute-volume observed in Figure 8 is caused

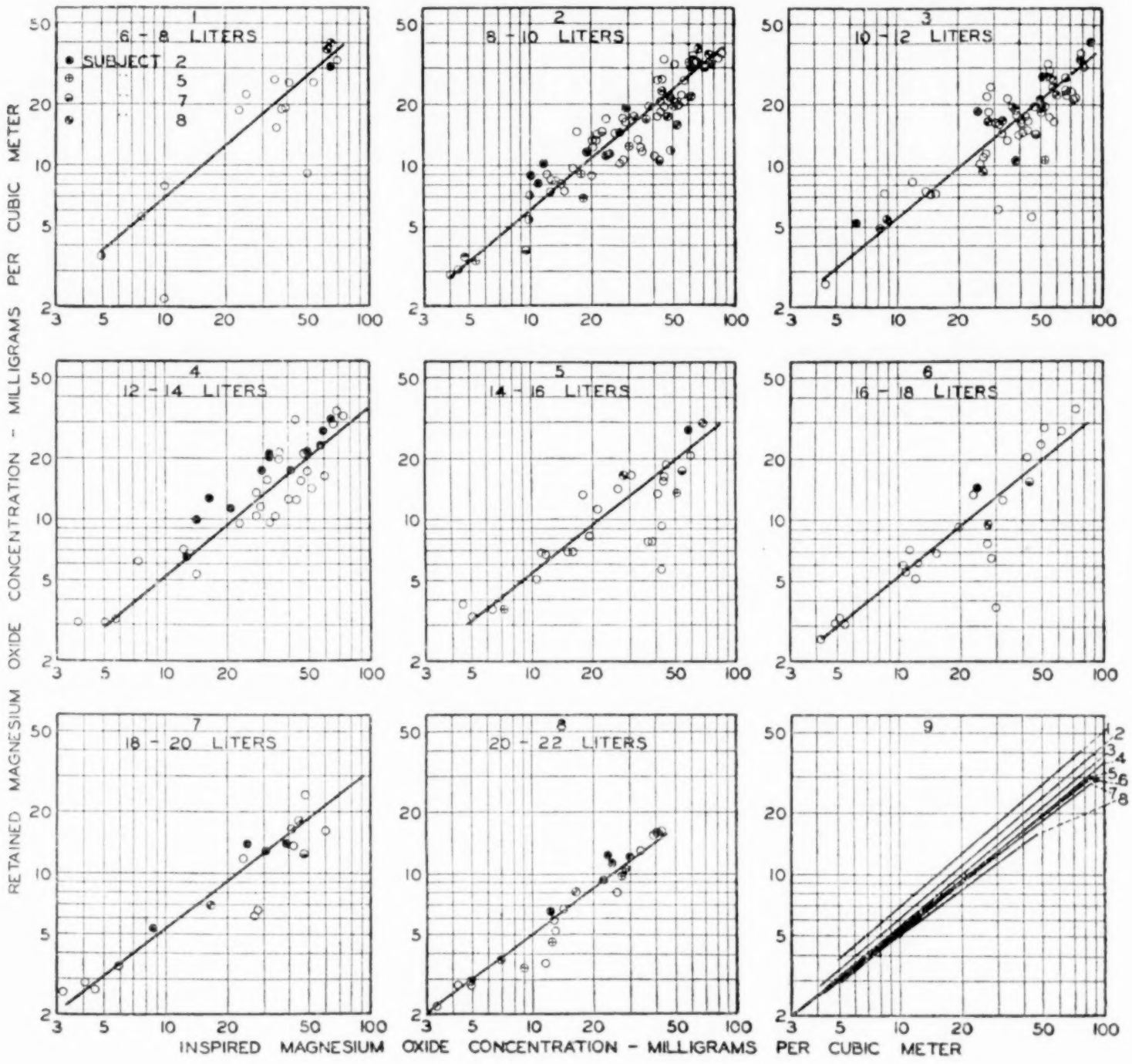


FIG. 8.—Retention of magnesium oxide at various minute-volumes.

The median values of minute-volume, respiration rate, and volume per respiration for the tests under the different breathing conditions are shown in Table 1. According to these figures, both the respiration rate and the volume per respiration appear to

in fact by the direct relation between respiration rate and minute-volume, and not by any specific influence of the latter upon dust retention.

*Vital Capacity.*—The vital capacities of the subjects in the dust retention experiments varied from 1,700

to 6,100 c.c. No indication was found that this wide difference affected retention significantly (see Fig. 3).

### *Physical Properties of Inspired Dust and Air*

*Size Characteristics of Inspired Dust.*—The amount of dust removed from an air stream, either by settlement, by impingement, or by filtration, depends in a measure upon the size properties of the suspended material. Surface area, volume, particle shape, density, and characteristics of flocculation or aggregation may be mentioned among the factors that affect the removal of dust in a physiologic structure such as the respiratory system, as well as in a physical structure. In a study of the problem of dust retention by man, it is desirable, therefore, to consider the size properties of the materials under investigation.

In order clearly to understand the significance of size in this problem, it is necessary at the outset to distinguish between *particle* size and *particulate* size. Particle size refers to the individual particles, whereas particulate size refers to the size of the masses or aggregates behaving as units. Since air suspended fumes and many dusts rarely occur in the form of individual particles, in the study of dust retention a knowledge of particulate size is probably more important than a knowledge of particle size. A knowledge of particle size, however, is of value in ascertaining the structure of the aggregates.

The particle sizes of the two dusts studied were determined by Green's method (5). Samples were dispersed on slides by means of a turpentine smear, and the particles were measured under oil immersion with a filar micrometer.

The particulate size of samples of the dust settling on slides at various intervals after cloud formation was studied under the microscope. The size and also the structure were observed under both light and dark field illumination, and photomicrographs were made at a magnification of 173 under dark field illumination.

The particle size measurement of magnesium oxide was discarded because of the large number of submicroscopic particles, as indicated in Figure

TABLE 1.—MEDIAN VALUES OF MINUTE-VOLUME, OF RESPIRATIONS PER MINUTE, AND OF VOLUME PER RESPIRATION FOR DIFFERENT BREATHING CONDITIONS

| BREATHING CONDITION | MINUTE-VOLUME[1,2] | RESPIRATIONS PER MINUTE | VOLUME[1] PER RESPIRATION |
|---|---|---|---|
| | *l.* | | *c.c.* |
| Resting—seated in chair | 10.5 | 17 | 617 |
| Exercising | 15.3 | 19 | 805 |
| Inhaling 5 per cent. carbon dioxide | 20.0 | 21 | 952 |

[1] Corrected to 21°C. and 760 mm.

[2] That these values are slightly higher than might be expected is owing to rebreathing (less than 100 c.c. per breath) through the dead space in the apparatus.

9. The size of the largest individual particles, however, was probably sufficiently accurate for our purpose. The size of these particles was very close to 1.5 microns, but the majority of all the particles were less than 1 micron. Whytlaw-Gray and his coworkers (6) describe the individual particles of magnesium oxide fume obtained from burning magnesium ribbon as minute cubic crystals, the greater number of which are "made up of minute apparent spheres, doubtless in reality cubes beyond the limit of resolution of the microscope."

The measurement of the particle size of the calcium carbonate just before cloud formation gave the following results: geometric mean 2.6 microns, standard geometric deviation 2.7, and size of largest particles about 15 microns. Particle size measurement of the same dust (Fig. 10) sampled by an Owens jet counter (7) about thirty hours after cloud formation gave the following parameters: geometric mean 0.6 micron, standard geometric deviation 1.7, and size of largest particle about 1.5 microns. Drinker, Thomson, and Finn (3) used the same calcium carbonate in their experiments and reported the particle size of a sample of the dust electrically precipitated from the inspired air on a celluloid foil to vary from 0.3 micron to 6 microns. The age of the cloud and the extent of aggregation were not given.

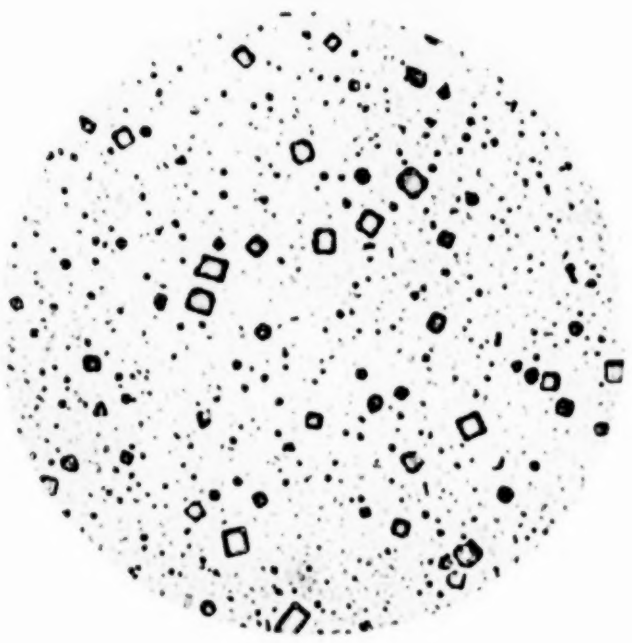

FIG. 9

FIG. 10

FIG. 9.—Particle size of magnesium oxide immediately after formation from ignited magnesium. × 1,285. Size of largest particle about 1.5 microns.

FIG. 10.—Particle size of calcium carbonate sampled by Owens' jet dust counter thirty hours after cloud formation. × 1,285. Particle size about 0.6 micron.

The particle size of the magnesium oxide remained constant, whereas that of the calcium carbonate decreased with the age of the cloud, owing to settlement of the larger particles. The geometric mean size of the latter decreased from 2.6 microns for the dust as thrown into the air to 0.6 micron for dust still suspended after thirty hours.

The particulate size of the magnesium oxide[4] increased with the age of the cloud; that of the calcium carbonate decreased. Photomicrographs of the two dusts settling out at various intervals after cloud formation are shown in Figure 11. The actual size of the particulate masses is not so important as the relative sizes of the two dusts and the change in the particulate size of the same dust with the age of the cloud. Roughly speaking, the particulate size of the magnesium oxide increased at about the same rate as that of the calcium carbonate decreased. At about 100 minutes after cloud formation the particulate size of the magnesium oxide was very close to that of the calcium carbonate. After this time the size of the magnesium oxide exceeded that of the calcium carbonate.

The change in particulate size with change in concentration and time is shown in Figures 12 and 13. The increase in particulate size and the decrease in concentration for magnesium oxide is fairly regular over a long period, at least twenty hours after cloud formation. The fact that the settling rate does not increase with an increase in the particulate size indicates that there is a difference in density between the individual particles and the aggregates. As a matter of fact, Whytlaw-Gray and his associates (11) have shown that the density of the aggregates of magnesium oxide in the fume is approximately one-tenth the density of the individual particles. They (6) describe the aggregates of magnesium oxide as "built up of minute cubic crystals frequently united by their corners into systems of considerable complexity. Some of

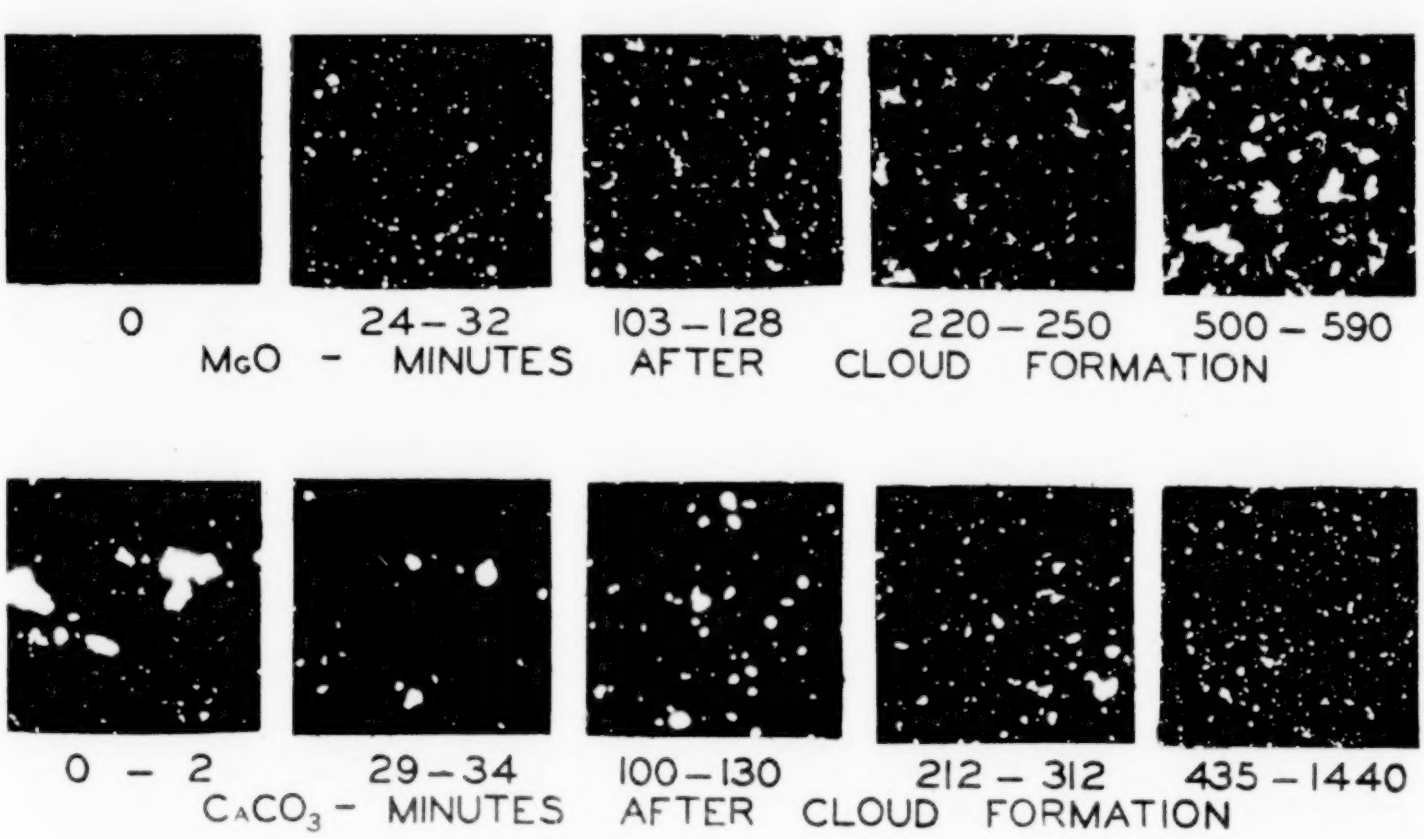


FIG. 11.—Variation in particulate size of magnesium oxide and calcium carbonate with age of cloud.

[4] The change in the particulate size of zinc oxide, which has physical properties similar to magnesium oxide, has been studied by Wells and Gerke (8); described by Gibbs (9); and photographically shown by Whytlaw-Gray and his associates (10).

he larger consist of a single cube with a few smaller cubes attached at various points."

The decrease in the particulate size and in the concentration of calcium carbonate (Fig. 13) took place in two stages. The first consisted in a rapid decrease, lasting for about an hour. The second stage, lasting several hours, was characterized by a much slower decrease, both in size and in concentration. The fact that the settling rate of the calcium carbonate fell sharply after the large particulate masses had disappeared indicates that there was not much difference in the density of the aggregates and the individual particles. Microscopic examination of the calcium carbonate settling out at various times after cloud formation showed that about one-half of the particulate masses were made up of aggregates consisting of few particles tightly packed together. Probably the aggregates were present in the dust before it was thrown up into a cloud.

According to Figure 5, for the same respiration rate, at all dust concentrations and for all ages of cloud, the percentage retention is higher for calcium carbonate than for magnesium oxide. In the case of observations made immediately after cloud formation this may be explained by the larger particulate size of the calcium carbonate. After about 100 minutes of cloud formation, however, the ag-

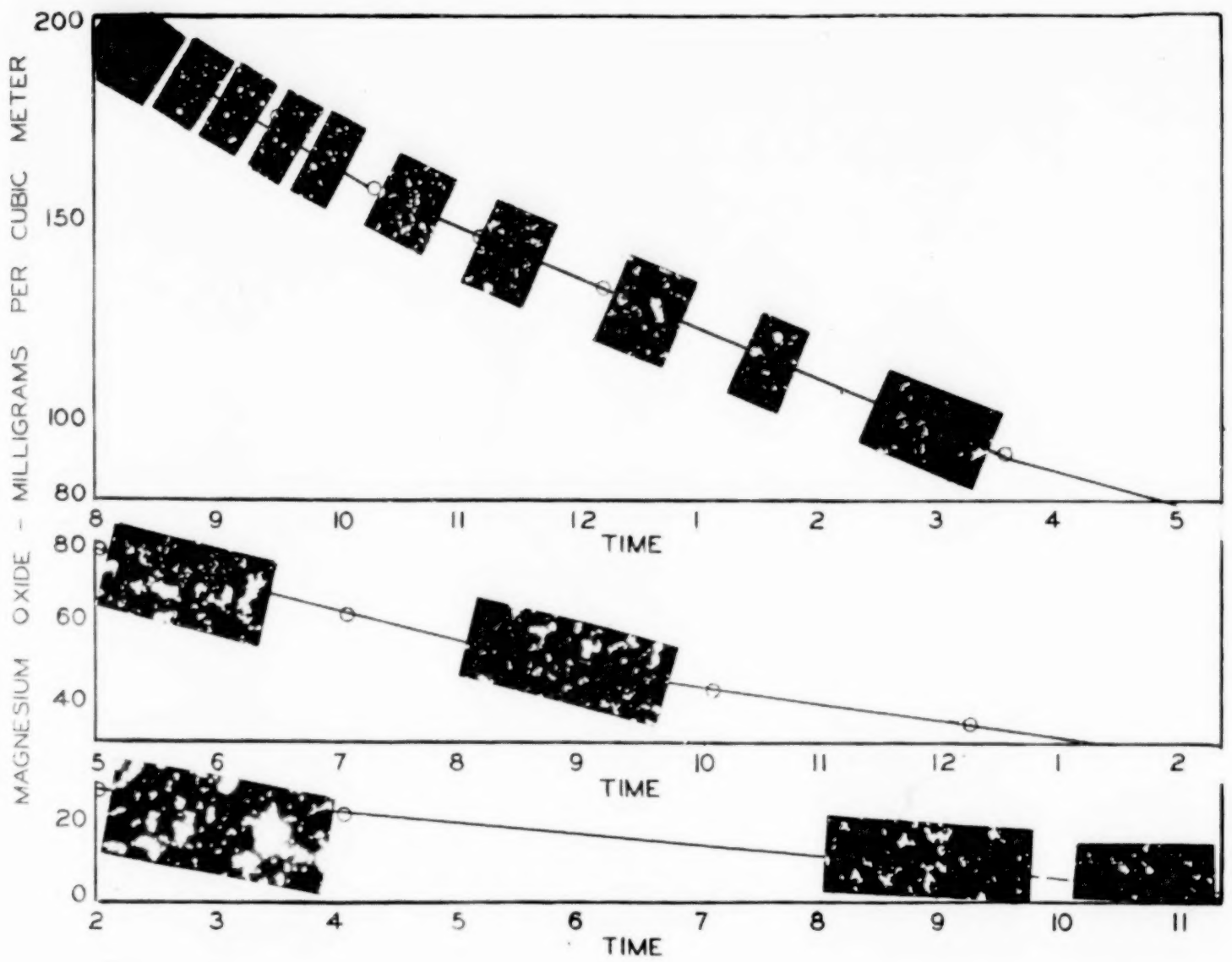


FIG. 12.—Change in particulate size of magnesium oxide with time and concentration.

gregates of magnesium oxide exceed in size the suspended calcium carbonate. The continued higher removal of the latter under this condition may be explained in the light of Whytlaw-Gray's observation of the lowered density of the aggregates of magnesium oxide as compared with calcium carbonate (0.35 and 2.7 to 2.9, respectively).

In the previous paper (1), a rapid increase was observed in the percentage retention with a decrease in the concentration of magnesium oxide in the inspired air. Since low dust concentrations were ordinarily associated with "old" clouds, it was thought that the rise in percentage retention might be caused by the increase in particulate size, observed in Figure 12. The error of this idea is shown by comparing the retention values from clouds 60±30 minutes old with those for the same dust concentrations from clouds having ages of 240 minutes or more (Fig. 14). No significant differences will be observed, thus indicating that concentration *per se* influences dust retention.

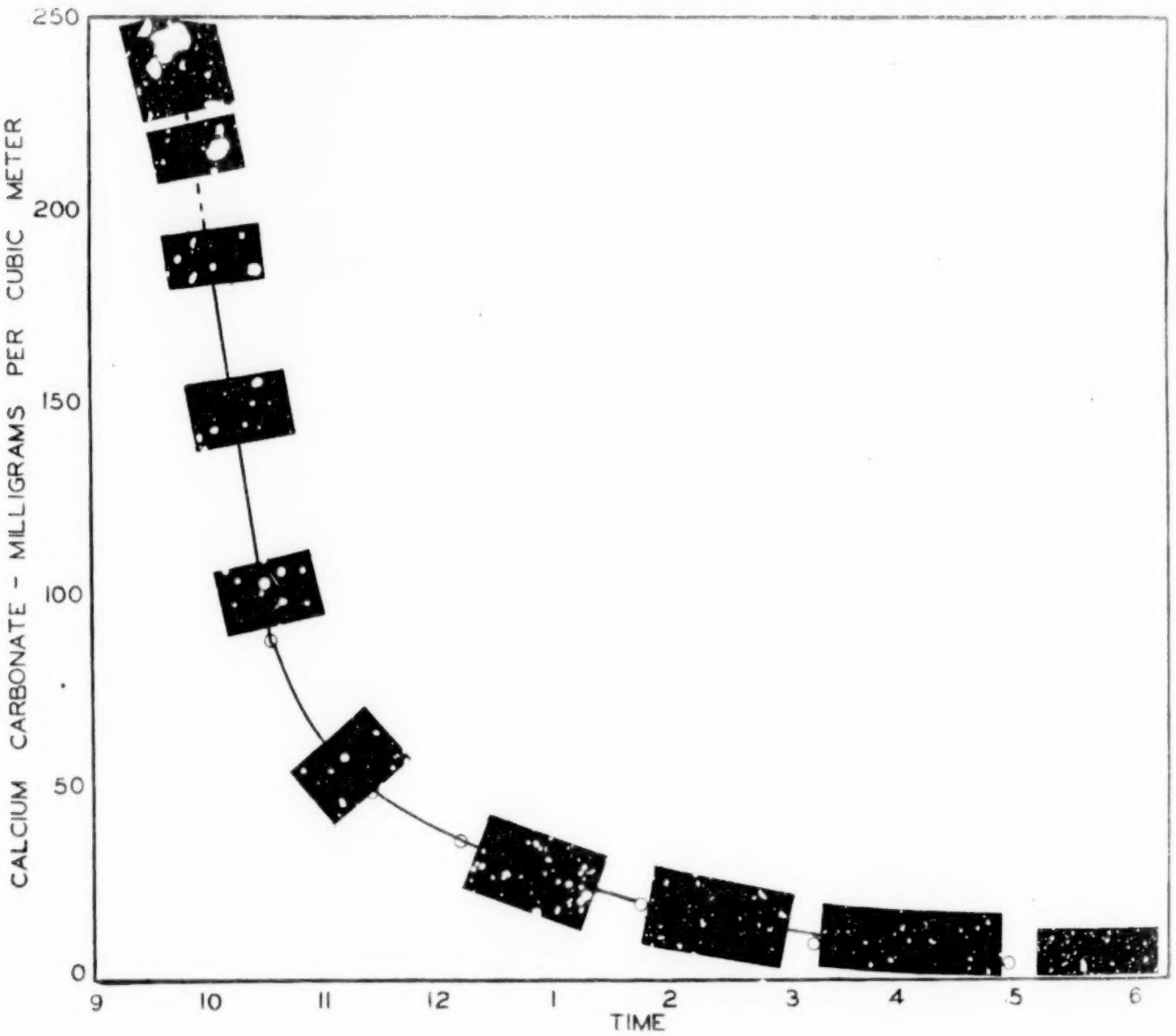


FIG. 13.—Change in particulate size of calcium carbonate with time and concentration.

The failure to demonstrate an increase in percentage retention with an increase in particulate size may again

be explained by the fact that the latter is accompanied by a decrease in density of the aggregates, with a possible balancing of the two factors.

The foregoing discussion of the influence of size upon the retention of dust, although not entirely satisfactory from a quantitative point of view, demonstrates clearly the complexity of this phase of the problem and indicates its importance in the study of dust retention by man.

*Wettability of Inspired Dust.*—The complexity of the changes with time and of certain physical properties such as adhesion and the like. Grossly, the factors involved in wettability may be said to be similar to the forces active in the retention of dust by the respiratory system.

The comparative wettabilities of magnesium oxide and calcium carbonate were determined by an arbitrary procedure. Clouds of dust were thrown up in the dust cabinet and settling curves obtained in the usual manner. At regular intervals the dusty air was drawn through an ordi-

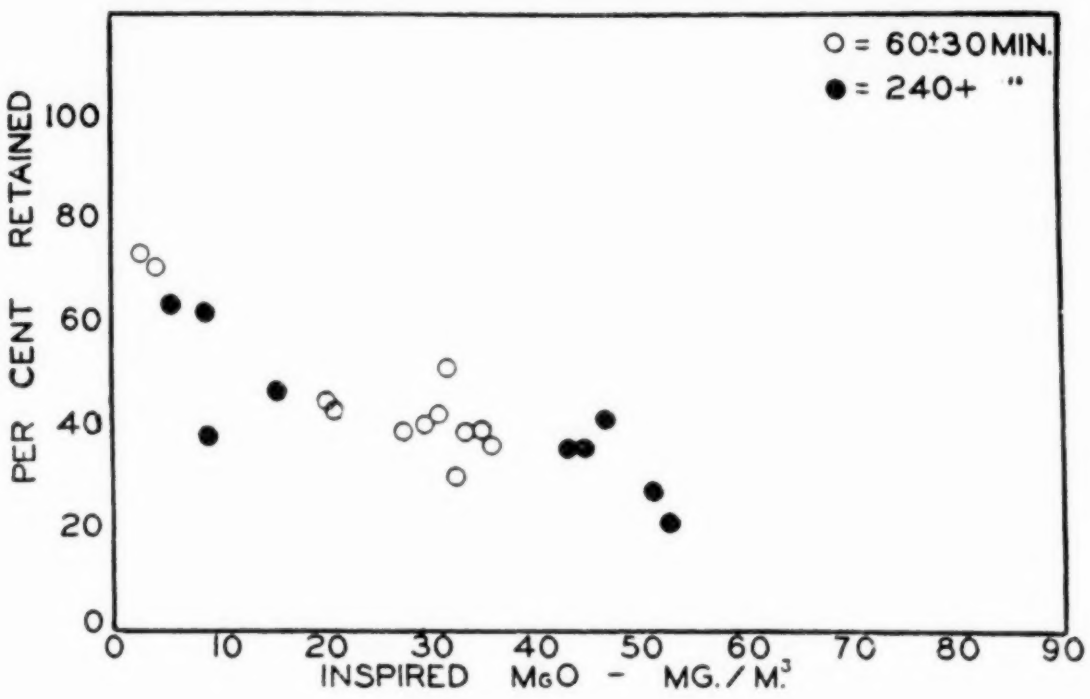


FIG. 14.—Effect of age of cloud on percentage retention of magnesium oxide.

in the size characteristics of air suspended dusts and fumes suggests the desirability of employing a simple physical index of the size properties of particulate materials in a study of their retention by man. Wettability, which is measured by the percentage removal of dust from an air stream when passing through water, offers certain desirable characteristics in this connection. The retention of dust in water is a function of the particulate size of the suspended material, of the nature of its surfaces, nary chemical gas bubbling bottle at the rate of 10 liters per minute for a given time, usually ten minutes. The dust passing through the bubbler was caught by electric precipitation and the amount of dust determined by chemical titration. The gas bubbler contained 200 c.c. of distilled water, which was sufficient to immerse the inlet tube to a depth of about 7.5 cm. The bottom of the inlet tube was approximately 0.5 cm. from the bottom of the bubbler. After each determination, the bubbler was rinsed

with distilled water and fresh water added. The same set-up and procedure were used for both dusts.

The results are presented in Figure 15. According to these curves, there is no change in the wettability of magnesium oxide throughout a period of cloud suspension of several hours. The percentage removal of calcium carbonate, on the other hand, decreases rapidly as the concentration falls below 50 mg. per cubic meter. Over a wide range of dust concentrations, the wettability of calcium carbonate appears to be significantly higher than that of magnesium oxide.

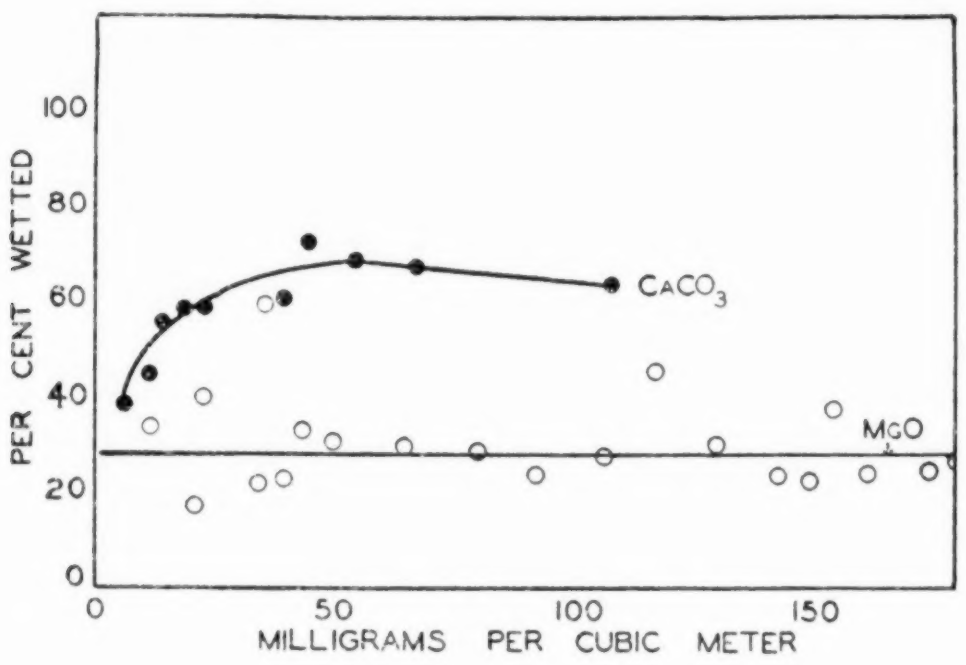


FIG. 15.—Percentage of magnesium oxide and calcium carbonate wetted in bubbling through water at rate of 10 liters per minute.

The results of the wetting experiments, although not in complete accord with those obtained from the studies of dust retention by man, appear to be similar in certain respects. In both cases calcium carbonate is retained to a greater extent than magnesium oxide. The decrease in wettability of calcium carbonate at low concentrations is associated with a reduction in particulate size, as shown in Figure 13, which indicates a decrease in size as the concentration fell below 50 mg. per cubic meter. The constant percentage removal of magnesium oxide over a wide range of concentrations, on the other hand, was associated with a marked increase in particulate size, as shown in Figure 12. This observation seems to corroborate the earlier statement that the increased flocculation of the particles is balanced by the accompanying decrease in density of the aggregates as far as these factors are concerned in the retention of dust.

That wettability is not a complete measure of the efficiency of the respiratory system as a dust collecting mechanism is indicated by a comparison between the retention curves in Figures 5 and 15. Concentration *per se* influences the retention of dust by man but appears not to determine the percentage removal by water except in so far as it is associated with changes in particulate size and density of the suspended material. Although the gross results on wettability and retention of magnesium oxide and calcium carbonate are similar, more work will have to be done before wet-

tability can be used as a measure of dust retention by man.

*Relative Humidity of Inspired Air.*—The relative humidity of inspired air affects the moisture of the mucous membranes of the upper respiratory passages. A low relative humidity tends to decrease the moisture of the mucous membranes and conceivably to affect the amount of dust retained.

Dust retention experiments were run over a range in relative humidity from about 40 per cent. to 95 per cent., but no appreciable effect on the retention of dust was noted. Perhaps more carefully controlled experiments might bring out some tendency, but the other factors involved far outweigh the effect of relative humidity.

## Discussion of Previous Work on Dust Retention

A review of the published data on the experimental determination of dust retention shows a considerable lack of agreement between the results of the various investigators. The data, summarized in Table 2, include values of percentage retention varying from about 11 per cent., reported by Weber (17), to 95 per cent., obtained by Lehmann and his associates (13). If the results obtained from experiments upon animals are excluded, the values range from 15 to 95 per cent.

The present study indicates that certain respiratory factors and physical properties of the suspended material were of considerable importance in the determination of the percentage retention of inspired dusts. These factors include: dust concentration, particulate size, density, wettability, and rate of respiration. A knowledge of their effect upon the percentage removal of inspired dust furnishes a basis for comparing and coordinating the results of the various investigators. Unfortunately, however, data in regard to the significant factors in dust retention by man are not present in all the literature on the subject, as is evident from the gaps in Table 2. Were this information available, probably the variations could be explained. Weber (17) suggested that the high results of Lehmann and his associates (13) may have been caused by the use of comparatively coarse dust. Baumberger's (14) results are in accord with those of this study if one assumes that the respiration rate during inhaling of tobacco smoke is less than during puffing. Variation in the method of dust determination, respiration rate, wettability, density, and concentration of the inspired dust would easily account for the variation in the results of Owens (16). The results for zinc oxide obtained by Drinker, Thomson, and Finn (3) are in exact agreement with those of the author on magnesium oxide, which has similar properties. On the other hand, Drinker's (3) results on marble dust are not within 15 per cent. of those of the present study although general conditions were similar. On the whole, the results of the different investigators on dust retention are probably in agreement, but for lack of essential data intelligent comparisons cannot be made. It is even more difficult to compare the work done on animals with the results obtained from human subjects. It is not known whether the factors discussed in the present paper apply with equal force in the case of animals. Moreover, differ-

TABLE 2.—SUMMARY OF RESULTS OBTAINED BY DIFFERENT INVESTIGATORS IN STUDIES IN DUST RETENTION

| INVESTIGATOR | SUBJECT | DUST | METHOD OF COLLECTING DUST | PARTICLE SIZE | INSPIRED DUST CONCENTRATION RANGE | DENSITY | WETTABILITY | RESPIRATIONS PER MINUTE | RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *μ* | *mg./cu.m.* | *gm./c.c.* | % | | % |
| Saito (12) | Dog and Rabbit | White Lead | Filter | .... | .... | .... | .... | .... | 14, 40 |
| Lehmann, Saito, and Gfrörer (13) | Men | White Lead | Filter | .... | .... | .... | .... | .... | 95 |
| Baumberger (14) | Men | Tobacco Smoke | Electric Precipitation | 0.25 | .... | .... | .... | Puffing | 67 |
| | | | | | | | | Inhaling | 88 |
| Sayers and associates (15) | Men | Lead Dust | Electric Precipitation | .... | 0.35–10.4 | .... | .... | .... | 15 |
| Owens (16) | Men | London Fog | Owens Counter | .... | .... | .... | .... | .... | 37–88 |
| Drinker, Thomson, and Finn (3) | Men | Zinc Oxide—Fume | Electric Precipitation | 0.4 | 50–450 | 5.42–5.78 | .... | 10 | 55 |
| | | Zinc Oxide—Kadox | | 0.15 | | | .... | 11 | 55 |
| | | Calcium Carbonate | | 0.3–6.0 | | 2.7 –2.9 | .... | 12 | 55 |
| Weber (17) | Dogs | Lead Oxide | Electric Precipitation | < 0.5 | 52–173 | .... | .... | .... | 11 |
| Brown (1) | Men | Magnesium Oxide | Electric Precipitation | < 1.5 | 3–80 | 0.35[1] | 28 | 10 | 55 |
| | | Calcium Carbonate | | <16.0 | | 2.7–2.9 | 60 | 12 | 73 |

[1] Density of aggregates.

ences in the structure of the respiratory tract of animals probably cause differences in retention. Determination of the ratio between percentage retention by man and by animals under similar conditions would be of considerable value as an aid in estimating the retention of very toxic dusts and fumes by man.

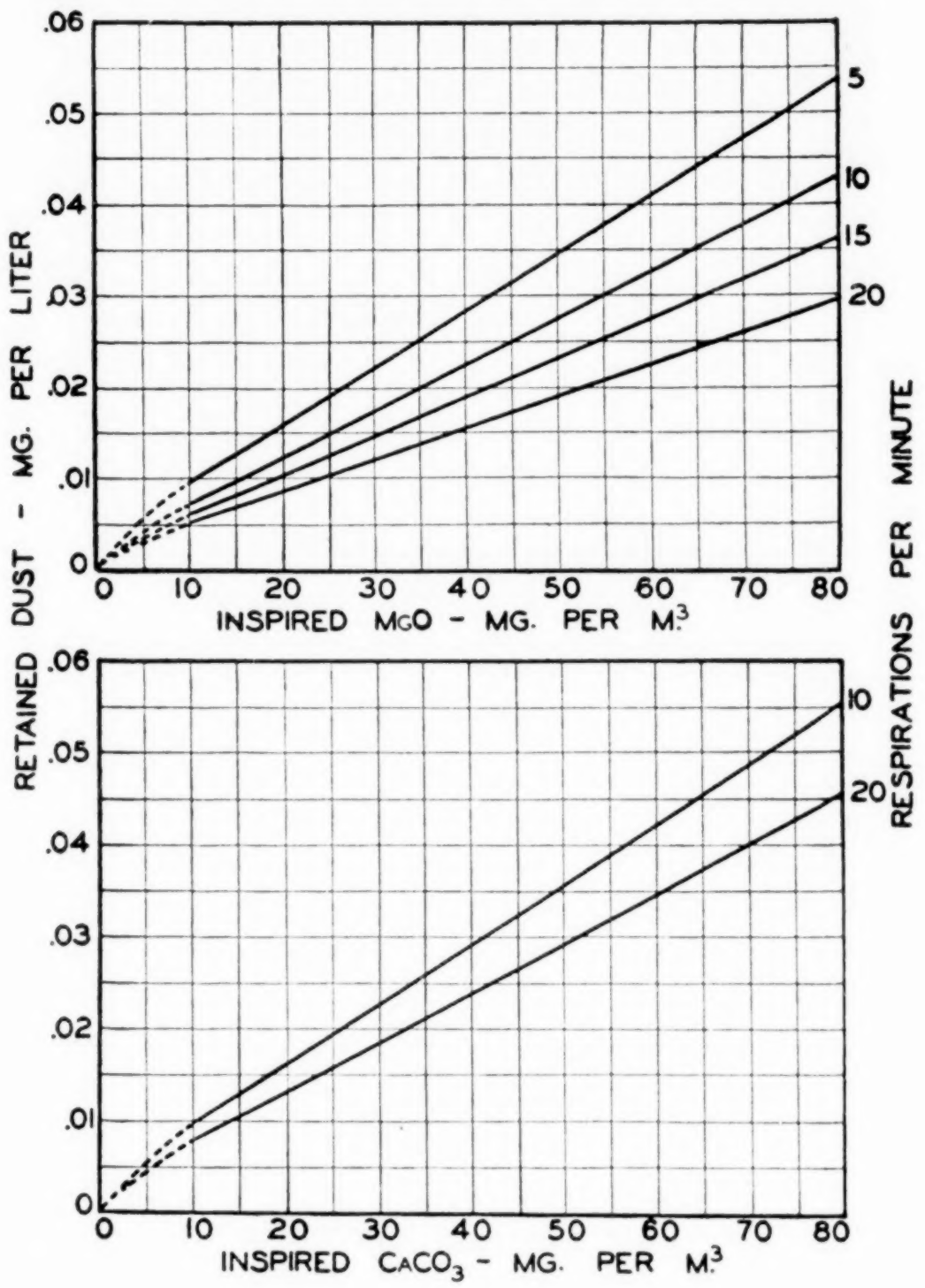


FIG. 16.—Retention of magnesium oxide and calcium carbonate at different respiration rates.

## DUST RETENTION CHART

The influence upon dust retention of the various factors discussed in this paper has been summarized graphically in Figure 16. The chart was constructed to cover the retention of magnesium oxide and calcium carbonate under all breathing conditions except by mouth, and extends over the range of inspired dust concentrations investigated: namely, from 3 to 80 mg. per cubic meter. Separate graphs are presented for the two substances, and for each material the actual amount of dust retained per liter is plotted against concentration

of inspired dust at stated rates of respiration.

For given conditions of inspired dust concentration and respiration rate, the actual amount, in milligrams, of magnesium oxide or calcium carbonate retained is found by multiplying the proper ordinate value by the liters of air breathed. The curves for a respiration rate of 20 per minute may be used for higher rates of breathing. The lines can be extended, at least in the case of magnesium oxide, to cover inspired dust concentrations up to 450 mg. per cubic meter (1).

The application of the curves in Figure 16 to dusts having similar physical properties seems questionable, although the results reported by Drinker, Thomson, and Finn (3) on the retention of zinc oxide both freshly formed and in the form of a powder (Kadox) were similar to those shown for magnesium oxide.

## Summary

Analysis of the data obtained from 418 dust retention experiments, using magnesium oxide in 363 and calcium carbonate in fifty-five, and employing thirty-two subjects breathing normally, shows that percentage retention varies with certain measurable factors:

1. Percentage retention is inversely proportional to respiration rate for rates below 20 per minute. An increase above 20 per minute is apparently followed by no change in percentage retention.

2. Percentage retention is inversely proportional to minute-volume of air breathed. This effect probably results from the increase in respiration rate with minute-volume.

3. Percentage retention is directly proportional to particulate size (not particle size) and to density of dust suspended in air.

4. Percentage retention is directly proportional to extent to which the dust is wetted in passing through water.

The results also show that percentage retention apparently is not affected by the following factors:

1. Volume per respiration.
2. Vital capacity.
3. Relative humidity of inspired air.

Published data on dust retention obtained by other investigators are summarized, but owing to the lack of essential information it is not possible to compare the results with those obtained in the present study. A chart summarizing the data on magnesium oxide and calcium carbonate is presented as a graphic aid in estimating dust retention by man.

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# HYPERTENSION IN INDUSTRY*

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WHILE extensive study and progress have been made in relation to infectious diseases, in comparison, very little progress has been made in regard to the degenerative diseases. There is generally thought to be a close relationship between infectious diseases and the onset and development of degenerative lesions. If this is true, we should expect a decrease in the incidence of degenerative diseases because there has been a decrease in the incidence of infectious diseases. Moreover, we should expect improved health in old age and an increase in length of life. From Warthin's study of old age (1, pp. 166–167), however, we have been led to believe otherwise. He states that the average length of life has been increased because more persons are allowed to reach the higher ages through the prevention of infectious diseases. There has been no increase, however, in the ratio of survivors to total population for ages 90 to 99.

From statistical studies of the degenerative diseases we have concluded that health in old age has not been improved, and that we continue to die at ages at which our forefathers died. Cardiovascular-renal disease is classed as a degenerative disease and causes more deaths than any other disease. Fahr (2) stated (1923) that in the United States approximately 50,000 persons die yearly from hypertension heart. He further stated that during 1924, 140,000 persons died of hypertension or its consequences (3). Elliott (4) stated that 10 per cent. of the people over 40 years of age have hypertension. Cabot (5) found that 77 per cent. of all heart disease without valvular lesions was due to hypertension or cardiovascular disease. Wychgel (6) showed that 73 per cent. of all his patients over 55 years of age had hypertension (from the Surgical Department of the American Steel and Wire Company, Cleveland, Ohio).

During the past year 527 men were studied in regard to the incidence of hypertension and concomitant findings. From this number, 422 were selected and studied as they came to us for physical examinations prior to employment. These men were chosen irrespective of findings, for the purpose of determining the incidence of hypertension. The remaining 105 men selected and studied were 55 or more years of age. They had been employed for a number of years and were called in for the purpose of this study. All examinations were made between the hours of 7 and 9 A.M. Many of the men were reexamined during the year. The standard for blood pressure

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findings was based on the work of J. W. Fisher, Medical Director of the Northwestern Mutual Life Insurance Company, as described by Norris, Bazett, and McMillan (7). None of our cases were classed as hypertension unless the blood pressure observations were from 12 to 15 mm. Hg above the stated normal.

TABLE 1.—FINDINGS IN 152 CONTROL CASES[1]

| AGE | NO. | OB | W | P | N | AM | F | OS | PH | VI | VAR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15–19 | | | | | | | | | | | |
| No. | 4 | 1 | 3 | 0 | 0 | 4 | 0 | 2 | 3 | 2 | 0 |
| % | 2.6 | 25.0 | 75.0 | 0.0 | 0.0 | 100.0 | 0.0 | 50.0 | 75.0 | 50.0 | 0.0 |
| 20–24 | | | | | | | | | | | |
| No. | 15 | 1 | 12 | 2 | 3 | 11 | 1 | 4 | 4 | 4 | 0 |
| % | 9.9 | 6.7 | 80.0 | 13.3 | 20.0 | 73.3 | 6.7 | 26.7 | 26.7 | 26.7 | 0.0 |
| 25–29 | | | | | | | | | | | |
| No. | 21 | 5 | 9 | 7 | 4 | 14 | 3 | 8 | 9 | 3 | 0 |
| % | 13.8 | 23.8 | 42.8 | 33.3 | 19.0 | 66.7 | 14.3 | 38.1 | 42.8 | 14.3 | 0.0 |
| 30–34 | | | | | | | | | | | |
| No. | 30 | 10 | 11 | 9 | 9 | 19 | 2 | 10 | 10 | 12 | 0 |
| % | 19.7 | 33.3 | 36.7 | 30.0 | 30.0 | 63.3 | 6.7 | 33.3 | 33.3 | 40.0 | 0.0 |
| 35–39 | | | | | | | | | | | |
| No. | 24 | 6 | 13 | 5 | 8 | 9 | 7 | 7 | 13 | 5 | 0 |
| % | 15.8 | 25.0 | 54.2 | 20.8 | 33.3 | 37.5 | 29.2 | 29.2 | 54.2 | 20.8 | 0.0 |
| 40–44 | | | | | | | | | | | |
| No. | 21 | 6 | 9 | 6 | 6 | 6 | 9 | 10 | 8 | 8 | 3 |
| % | 13.8 | 28.5 | 42.9 | 28.5 | 28.5 | 28.5 | 42.9 | 47.6 | 38.1 | 38.1 | 14.3 |
| 45–49 | | | | | | | | | | | |
| No. | 12 | 4 | 2 | 6 | 3 | 8 | 1 | 4 | 7 | 5 | 0 |
| % | 7.9 | 33.3 | 16.7 | 50.0 | 25.0 | 66.7 | 8.3 | 33.3 | 58.3 | 41.7 | 0.0 |
| 50–54 | | | | | | | | | | | |
| No. | 3 | 2 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 0 |
| % | 2.0 | 66.7 | 33.3 | 0.0 | 0.0 | 33.3 | 66.7 | 0.0 | 0.0 | 100.0 | 0.0 |
| 55–59 | | | | | | | | | | | |
| No. | 14 | 3 | 6 | 5 | 2 | 8 | 4 | 7 | 4 | 9 | 2 |
| % | 9.2 | 21.4 | 42.8 | 35.7 | 14.3 | 57.1 | 28.6 | 50.0 | 28.6 | 64.3 | 14.3 |
| 60–64 | | | | | | | | | | | |
| No. | 5 | 0 | 2 | 3 | 1 | 2 | 2 | 1 | 1 | 5 | 1 |
| % | 3.3 | 0.0 | 40.0 | 60.0 | 20.0 | 40.0 | 40.0 | 20.0 | 20.0 | 100.0 | 20.0 |
| 65–74 | | | | | | | | | | | |
| No. | 3 | 0 | 2 | 1 | 0 | 1 | 2 | 1 | 1 | 2 | 0 |
| % | 2.0 | 0.0 | 66.7 | 33.3 | 0.0 | 33.3 | 66.7 | 33.3 | 33.3 | 66.7 | 0.0 |
| Total.. | 152 | 38 | 70 | 44 | 36 | 83 | 33 | 54 | 60 | 58 | 6 |
| % .... | 100.0 | 25.0 | 46.1 | 28.9 | 23.7 | 54.6 | 21.7 | 35.5 | 39.5 | 38.2 | 3.9 |

[1] OB = obesity; W = well nourished; P = poorly nourished; N = negro; AM = American whites; F = foreign born; OS = oral sepsis; PH = past history of diseases; VI = impaired vision; and VAR = varicosities.

Of the total 422 cases, 152, or 36 per cent., showed definite blood pressure findings above the normal. A series

of 152 normal subjects were studied as a control group. Of the 105 men over 55 years of age, sixty-seven, or 63.8 per cent., were definitely hypertensive. All these cases were divided into age groups of five-year intervals, beginning with the age of 15 and including ages 65 to 75. These respective age groups were then studied in relation to nutrition, nationality, oral sepsis, past diseases, vision, symptoms and findings, and varicosities.

TABLE 2.—FINDINGS IN 152 CASES OF HYPERTENSION[1]

| AGE | NO. | OB | W | P | N | AM | F | OS | PH | VI | SY | VAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15–19 | | | | | | | | | | | | |
| No. | 5 | 2 | 2 | 1 | 1 | 4 | 0 | 1 | 2 | 0 | 3 | 0 |
| % | 3.3 | 40.0 | 40.0 | 20.0 | 20.0 | 80.0 | 0.0 | 20.0 | 40.0 | 0.0 | 60.0 | 0.0 |
| 20–24 | | | | | | | | | | | | |
| No. | 13 | 2 | 6 | 5 | 5 | 8 | 0 | 9 | 5 | 3 | 9 | 0 |
| % | 8.6 | 15.4 | 46.2 | 38.5 | 38.5 | 61.5 | 0.0 | 69.2 | 38.5 | 23.1 | 69.2 | 0.0 |
| 25–29 | | | | | | | | | | | | |
| No. | 13 | 4 | 6 | 3 | 6 | 5 | 2 | 7 | 6 | 2 | 7 | 0 |
| % | 8.6 | 30.8 | 46.2 | 23.1 | 46.2 | 38.5 | 15.4 | 53.8 | 46.2 | 15.4 | 53.8 | 0.0 |
| 30–34 | | | | | | | | | | | | |
| No. | 8 | 5 | 2 | 1 | 2 | 4 | 2 | 4 | 4 | 5 | 5 | 0 |
| % | 5.3 | 62.5 | 25.0 | 12.5 | 25.0 | 50.0 | 25.0 | 50.0 | 50.0 | 62.5 | 62.5 | 0.0 |
| 35–39 | | | | | | | | | | | | |
| No. | 23 | 6 | 8 | 9 | 5 | 11 | 7 | 12 | 9 | 13 | 7 | 0 |
| % | 15.1 | 26.1 | 34.8 | 39.1 | 21.7 | 47.8 | 30.4 | 52.2 | 39.1 | 56.5 | 30.4 | 0.0 |
| 40–44 | | | | | | | | | | | | |
| No. | 23 | 7 | 9 | 7 | 3 | 9 | 11 | 10 | 6 | 14 | 8 | 2 |
| % | 15.1 | 30.4 | 39.1 | 30.4 | 13.0 | 39.1 | 47.8 | 43.5 | 26.1 | 60.9 | 34.8 | 8.7 |
| 45–49 | | | | | | | | | | | | |
| No. | 20 | 4 | 7 | 9 | 4 | 4 | 12 | 4 | 6 | 15 | 3 | 2 |
| % | 13.2 | 20.0 | 35.0 | 45.0 | 20.0 | 20.0 | 60.0 | 20.0 | 30.0 | 75.0 | 15.0 | 10.0 |
| 50–54 | | | | | | | | | | | | |
| No. | 8 | 2 | 3 | 3 | 2 | 2 | 4 | 3 | 2 | 7 | 3 | 2 |
| % | 5.3 | 25.0 | 37.5 | 37.5 | 25.0 | 25.0 | 50.0 | 37.5 | 25.0 | 87.5 | 37.5 | 25.0 |
| 55–59 | | | | | | | | | | | | |
| No. | 11 | 5 | 4 | 2 | 0 | 6 | 5 | 7 | 7 | 10 | 5 | 2 |
| % | 7.2 | 45.5 | 36.4 | 18.2 | 0.0 | 54.5 | 45.5 | 63.6 | 63.6 | 90.9 | 45.5 | 18.2 |
| 60–64 | | | | | | | | | | | | |
| No. | 17 | 4 | 3 | 10 | 1 | 6 | 10 | 11 | 3 | 13 | 9 | 4 |
| % | 11.1 | 23.5 | 17.6 | 58.8 | 5.9 | 35.3 | 58.8 | 64.7 | 17.6 | 76.5 | 52.9 | 23.5 |
| 65–74 | | | | | | | | | | | | |
| No. | 11 | 2 | 5 | 4 | 1 | 4 | 6 | 8 | 4 | 11 | 6 | 4 |
| % | 7.2 | 18.2 | 45.5 | 36.4 | 9.1 | 36.4 | 54.5 | 72.7 | 36.4 | 100.0 | 54.5 | 36.4 |
| Total.. | 152 | 43 | 55 | 54 | 30 | 63 | 59 | 76 | 54 | 93 | 65 | 16 |
| %..... | 100.0 | 28.3 | 36.2 | 35.5 | 19.7 | 41.4 | 38.8 | 50.0 | 35.5 | 61.2 | 42.8 | 10.5 |

[1] SY = symptoms. Other symbols as in Table 1.

Tables 1, 2, and 3 represent the findings in the control group, in the hypertensive group, and in the men over 55 years of age. Figures 1 and 2

represent the average blood pressure findings for each age period of the 152 cases of hypertension from ages 15 to 75 and of the sixty-seven cases of hypertension over 55 years of age.

TABLE 3.—FINDINGS IN 105 CASES 55 OR MORE YEARS OF AGE, AND IN 67 CASES OF SAME AGES WITH HYPERTENSION[1]

| AGE | NO. | OB | W | P | N | AM | F | TE | TO | GU | VI | VAR | SY | HR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *105 Cases of Ages above 55* | | | | | | | | | | | | | | |
| 55–59 | | | | | | | | | | | | | | |
| No. | 37 | 15 | 14 | 8 | 1 | 19 | 17 | 12 | 2 | 10 | 30 | 16 | 4 | 15 |
| % | 35.2 | 40.5 | 37.8 | 21.6 | 2.7 | 51.4 | 45.9 | 32.4 | 5.4 | 27.0 | 81.1 | 43.2 | 10.8 | 40.5 |
| 60–64 | | | | | | | | | | | | | | |
| No. | 44 | 15 | 15 | 14 | 5 | 16 | 23 | 26 | 3 | 15 | 41 | 8 | 22 | 24 |
| % | 41.9 | 34.1 | 34.1 | 31.8 | 11.4 | 36.4 | 52.3 | 59.1 | 6.8 | 34.1 | 93.2 | 18.2 | 50.0 | 54.5 |
| 65–69 | | | | | | | | | | | | | | |
| No. | 21 | 4 | 10 | 7 | 0 | 6 | 15 | 14 | 1 | 10 | 18 | 10 | 14 | 12 |
| % | 20.0 | 19.0 | 47.6 | 33.3 | 0.0 | 28.5 | 71.4 | 66.7 | 4.8 | 47.6 | 85.7 | 47.6 | 66.7 | 57.1 |
| 70–74 | | | | | | | | | | | | | | |
| No. | 3 | 0 | 1 | 2 | 0 | 2 | 1 | 2 | 0 | 2 | 2 | 0 | 2 | 0 |
| % | 2.9 | 0.0 | 33.3 | 66.7 | 0.0 | 66.7 | 33.3 | 66.7 | 0.0 | 66.7 | 66.7 | 0.0 | 66.7 | 0.0 |
| Total.. | 105 | 34 | 40 | 31 | 6 | 43 | 56 | 54 | 6 | 37 | 91 | 34 | 42 | 51 |
| %..... | 100.0 | 32.4 | 38.1 | 29.5 | 5.7 | 41.0 | 53.3 | 51.4 | 5.7 | 35.2 | 86.7 | 32.4 | 40.0 | 48.6 |
| *67 Cases of Hypertension of Ages above 55* | | | | | | | | | | | | | | |
| 55–59 | | | | | | | | | | | | | | |
| No. | 21 | 7 | 9 | 5 | 0 | 8 | 13 | 8 | 0 | 11 | 18 | 10 | 3 | 11 |
| % | 31.3 | 33.3 | 42.9 | 23.8 | 0.0 | 38.1 | 61.9 | 38.1 | 0.0 | 52.4 | 85.7 | 47.6 | 14.3 | 52.4 |
| 60–64 | | | | | | | | | | | | | | |
| No. | 32 | 12 | 12 | 8 | 4 | 13 | 15 | 18 | 2 | 9 | 28 | 6 | 17 | 17 |
| % | 47.8 | 37.5 | 37.5 | 25.0 | 12.5 | 40.6 | 46.9 | 56.3 | 6.3 | 28.1 | 87.5 | 18.8 | 53.1 | 53.1 |
| 65–69 | | | | | | | | | | | | | | |
| No. | 14 | 4 | 5 | 5 | 0 | 6 | 8 | 9 | 1 | 8 | 13 | 7 | 12 | 7 |
| % | 20.9 | 28.6 | 35.7 | 35.7 | 0.0 | 42.8 | 57.1 | 64.2 | 7.1 | 57.1 | 92.9 | 50.0 | 85.7 | 50.0 |
| Total.. | 67 | 23 | 26 | 18 | 4 | 27 | 36 | 35 | 3 | 28 | 59 | 23 | 32 | 35 |
| %..... | 100.0 | 34.3 | 38.8 | 26.9 | 6.0 | 40.3 | 53.7 | 52.2 | 4.5 | 41.8 | 88.1 | 34.3 | 47.8 | 52.2 |

[1] TE = dental caries; TO = tonsillar infection; GU = gum infection; and HR = hernia. Other symbols as in Tables 1 and 2.

The average blood pressure for the age group 15 to 19 was 144.8/77.2, and the average pulse pressure 67.6. The ratio of pulse pressure to diastolic pressure was 88 per cent. The average normal blood pressure for this group was 118.3/75.3, with a pulse pressure to diastolic pressure ratio of 57 per cent.

The average blood pressure of the group 20 to 24 was 149.2/83.2, and the pulse pressure 66. The ratio of pulse pressure to diastolic pressure was 79

per cent. The average normal blood pressure for this group was 121/77, with a pulse pressure of 44 and a pulse pressure to diastolic pressure ratio of 57 per cent. The highest blood pressure found was 170/80, and the lowest 140/60.

highest systolic blood pressure found was 190, and the lowest was 144.

For the age group 30 to 34 the average normal blood pressure was 122.5/79.8, with a pulse pressure of 42.7 and a pulse pressure to diastolic pressure ratio of 53 per cent. The

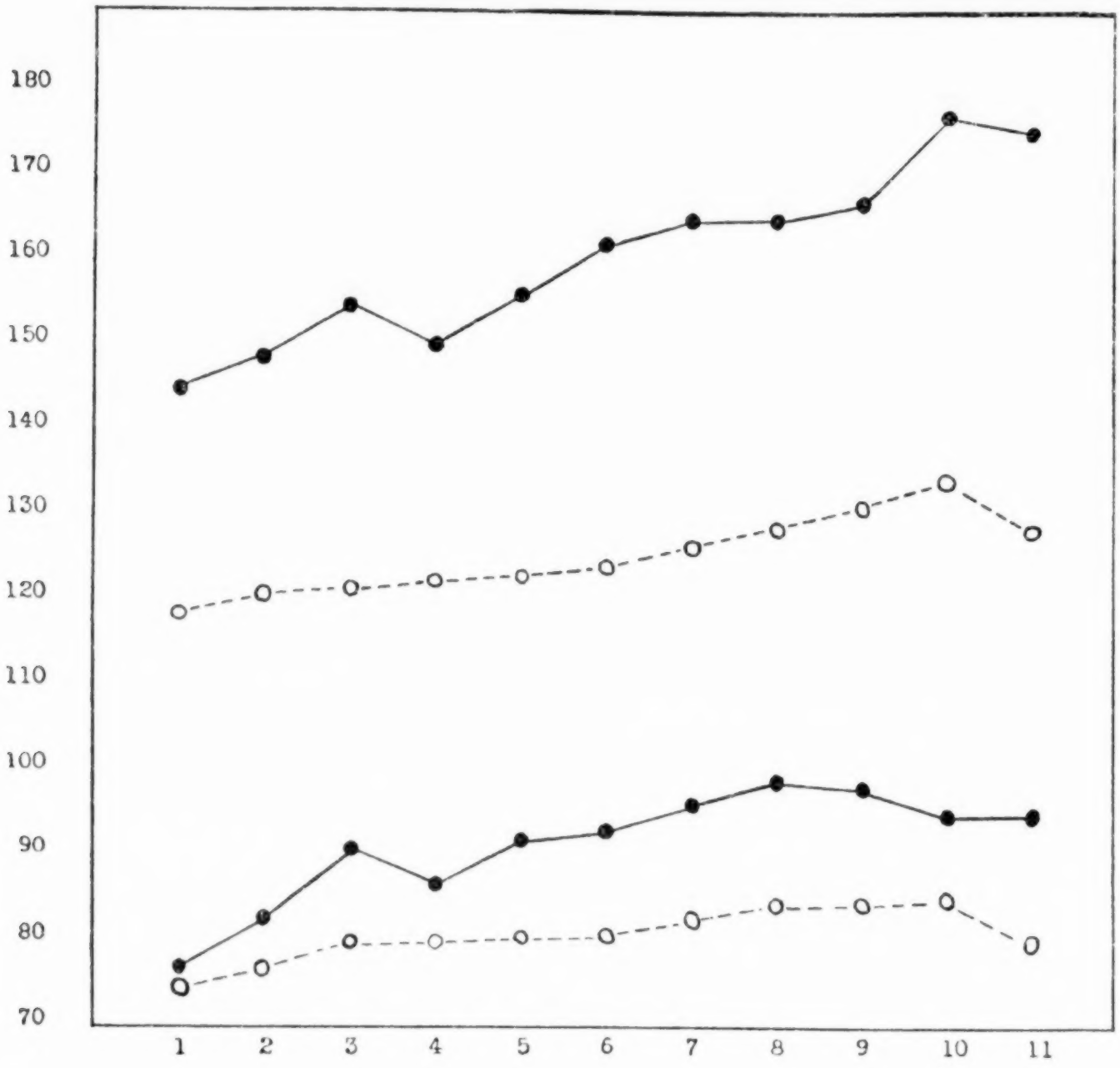


FIG. 1.—Average blood pressure findings of each age period for the 152 cases of hypertension (solid lines) compared with normal blood pressure (broken lines) for each age period.
1 = 15–19; 2 = 20–24; 3 = 25–29; 4 = 30–34; 5 = 35–39; 6 = 40–44; 7 = 45–49; 8 = 50–54; 9 = 55–59; 10 = 60–64; 11 = 65–74.

For the age group 25 to 29 the average normal pressure was 121.8/78.6. The average for this group in our cases was 155.1/91.5, with a pulse pressure of 63.6, or a pulse pressure to diastolic pressure ratio of 69 per cent. (normal was 55 per cent.). The

average found for this group was 149.6/87.5, with a pulse pressure of 62.1 and a pulse pressure to diastolic pressure ratio of 70 per cent. The highest pressure found was 160/100, and the lowest 144/80.

The average normal blood pressure

for the group 35 to 39 was 123.2/80.8, with a pulse pressure of 42.4 and a pulse pressure to diastolic pressure ratio of 52 per cent. The average blood pressure found was 156/92, with a pulse pressure of 64 and a pulse pressure to diastolic pressure ratio of 70 per cent. The highest blood pressure found was 180/110, and the lowest 140/100.

For the age group 40 to 44 the average normal blood pressure was 124.6/81.8, with a pulse pressure of 42.8 and a pulse pressure to diastolic pressure ratio of 52 per cent. The average blood pressure found was 162.5/93.3, with a pulse pressure of 69.2 and a pulse pressure to diastolic pressure ratio of 74 per cent. The highest blood pressure found was 210/90, the lowest was 142/100.

For the age group 45 to 49 the average normal blood pressure was 126.6/82.8, with a pulse pressure of 43.8 and a pulse pressure to diastolic pressure ratio of 53 per cent. The average blood pressure found was 165.5/95.9, with a pulse pressure of 69.6 and a pulse pressure to diastolic pressure ratio of 73 per cent. The highest pressure found was 210/112, and the lowest was 150/90.

The average normal blood pressure for the age group 50 to 54 was 128.8/84, with a pulse pressure of 44.8 and a pulse pressure to diastolic pressure ratio of 53 per cent. The average blood pressure found for this group was 165/98.7, with a pulse pressure of 66.3 and a pulse pressure to diastolic pressure ratio of 67 per cent. The highest blood pressure found was 190/110; the lowest was 150/80.

The average normal blood pressure for the age group 55 to 59 was 131.4/84.6, with a pulse pressure of 46.8 and a pulse pressure to diastolic pressure ratio of 55 per cent. The blood pressure found for this group was 167/98.1, with a pulse pressure of 68.9 and a pulse pressure to diastolic pressure ratio of 70 per cent. The highest blood pressure found was 170/100, and the lowest was 150/90. In the group of cases over 55 years of age studied separately from the other groups and consisting of men who have been with this industry for a number of years, the average blood pressure found was 171/93, with a pulse pressure of 78 and a pulse pressure to diastolic pressure ratio of 84 per cent.

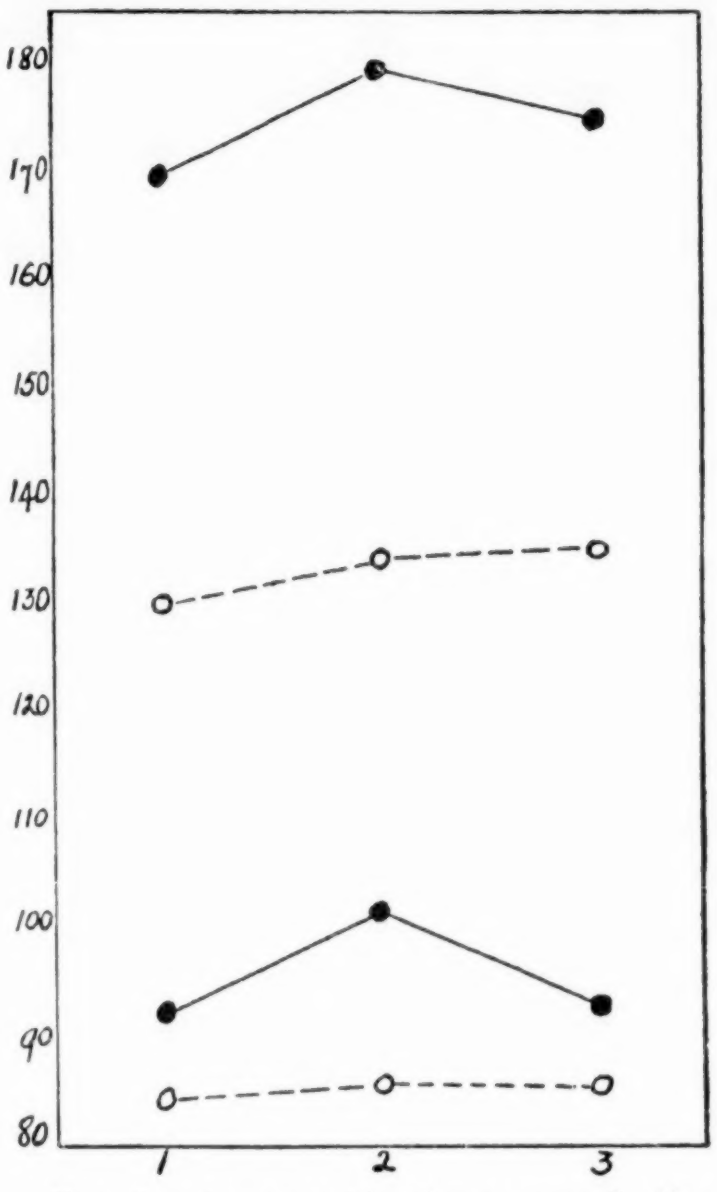


FIG. 2.—Average blood pressure findings for the 67 cases of hypertension of ages above 55 (solid lines) compared with normal blood pressure for each age period (broken lines). 1 = 55–59; 2 = 60–64; 3 = 65–74.

The average normal blood pressure for the age group 60 to 64 was 134.5/85.4, with a pulse pressure of 49.1 and a pulse pressure to diastolic pressure ratio of 57 per cent. The average blood pressure found was 177.1/94.8, with a pulse pressure of 82.3 and a pulse pressure to diastolic pressure ratio of 87 per cent. The highest blood pressure found was 230/140, and the lowest 150/90. Among the thirty-two cases over 55 years of age the average blood pressure found was 180/103, with a pulse pressure of 77 and a pulse pressure to diastolic pressure ratio of 75 per cent.

For the age group 65 to 75 the average normal blood pressure was 128/80, with a pulse pressure of 48 and a pulse pressure to diastolic pressure ratio of 60 per cent. The average blood pressure for this group was 175.4/95, with a pulse pressure of 80.4 and a pulse pressure to diastolic pressure ratio of 85 per cent. The highest blood pressure found was 298/120, and the lowest 150/80. Among the cases over 55 years of age studied at this age period the average blood pressure found was 176/94, with a pulse pressure of 82 and a pulse pressure to diastolic pressure ratio of 87 per cent.

### Age Distribution

In the whole group of 304 cases (152 cases of hypertension and 152 control cases) there was a gradual increase in the number of cases in each age period up to 35 to 39 (15.1 per cent.). From this age period to that of 50 to 54 there was a gradual decrease (3.6 per cent.). The following period, 55 to 59, showed a slight increase to 8.2 per cent., with a gradual tapering off to 4.6 per cent. for the age period 65 to 74.

In the control group of 152 cases the peak of the distribution curve was at the age period 30 to 34 (19.8 per cent.) with a gradual decrease to the period 50 to 54 (2 per cent.). This was followed by a slight increase to the period 55 to 59 (9.2 per cent.), with a gradual decrease again to the age period 65 to 74 (1.9 per cent.).

In the hypertensive group of 152 cases the peak of the distribution curve was at the age periods 35 to 44 (15.1 per cent.). This was preceded by a gradual increase up to the age period 25 to 29, which was followed by a decrease for the period 30 to 34. Following the age groups 35 to 44 there occurred a fall in the distribution curve for the next two periods, and then an increase again until at the age period 60 to 64 it reached 11.1 per cent. This was followed by a drop to 7.2 per cent. in the age group 65 to 74.

For the 105 cases over 55 years of age the peak of the distribution curve occurred at the age period 60 to 64 (41.9 per cent.). It was at this same age period that the distribution curve reached its peak in the sixty-seven cases of hypertension (47.8 per cent.).

The interesting feature here was the similarity between the age distribution curve and the blood pressure, obesity, and oral sepsis curves. The percentage of cases of the hypertensive group increased above that of the whole and the control groups from the age period 35 to 39.

### Incidence of Obesity

In the whole group there was a gradual tendency for a decrease in weight throughout all age periods.

There was a slight increase at 50 to 54, but in general there was a downward trend. The control group showed a gradual increase in weight up to the age period 45 to 49. At this point there was a sharp increase for the age period 50 to 54. Following this there was a drop, so that by the age periods 60 to 64 and 65 to 74 there was no obesity. In the hypertensive group the weight curve suddenly increased at the age period 30 to 34 to as high as 62.5 per cent. From this period the drop was again sudden with only a slight increase at 55 to 59, which was followed by a drop. The average obesity incidence was higher in the hypertensive group (28.4 per cent.) than in the control group (25 per cent.). The incidence of obesity in the sixty-seven cases of hypertension over 55 years of age was 34.3 per cent.—higher than in the other hypertensive group or in the control group.

The relation of obesity to hypertension has long been observed and taught. The comparison of the incidence of obesity in the different groups revealed no marked variation. From this study and other observations in this regard, we have felt that obesity as a cause for hypertension is farfetched. Too often we have observed obesity concurrent with normal blood pressures and, in fact, frequently with subnormal pressures. Hypertension and obesity may be coincidental. Both follow hereditary tendencies. The etiology of one may be the etiology of the other.

In another series of sixty-five obese men selected promiscuously, forty-three had normal blood pressure and twenty-two, or 33.8 per cent., had blood pressure findings 15 points or more above the normal.

In this connection the blood cholesterol (8) was studied in seventeen cases selected from the group of 152 cases of hypertension. Twelve, or 70 per cent., showed a blood cholesterol definitely above the normal. The average blood cholesterol of this small series of seventeen cases was 271.18 mg. per 100 c.c. of blood. The highest was 357.1 mg., and the lowest 218.6 mg. Nothing definite can be said of cholesterol as an etiologic factor for hypertension. We know that cholesterol is high in diabetes (9). Diabetics are subject to arteriosclerosis. The blood cholesterol, however, is found high in nephrosis (10) which is not characterized by an increase in blood pressure. Westphal (11) considered high cholesterolemia important in producing hypertension. He found a high cholesterol content of the blood in 71 per cent. of his cases of essential hypertension.

### Race Incidence

The highest percentage of foreign born occurred in the 152 cases of elevated blood pressure—38.8 per cent., as compared with 21.7 per cent. in the control group and 30.2 per cent. in the whole group. In the hypertensive group the American whites and negroes constituted 41.4 and 19.7 per cent., respectively. In the control group the percentages were 54.6 and 23.7, respectively. In the cases over 55 years of age foreign born occurred to the extent of 53.3 per cent., American whites 41 per cent., and negroes 5.7 per cent. This relationship remained practically the same in the sixty-seven cases with hypertension.

The foreign born predominated (53.7 per cent.).

The incidence of foreign born, compared with the control group, increased above all other races in the high blood pressure group. Most of these were from Central Europe; a few were from Scandinavia and Italy. The foreign born tended more to obesity, overeating, and indulgence in tobacco and alcoholic beverages. They also appeared to be a nervous, unstrung, worrying, and high pressure type of individuals.

### Incidence of Oral Sepsis

Throughout practically all age periods oral sepsis tended to be higher in the hypertensive group than in the control group or in the whole group. The incidence in these three groups was 50, 35.5, and 42.8 per cent., respectively. The difference in rates was striking, and personally, we believe that it cannot be dismissed lightly. Among the cases over 55 years of age oral infection occurred in 92.3 per cent.; in the cases with hypertension, it was present in 98.5 per cent. In this class of persons pyorrhea and tooth and tonsillar infections were appallingly high. Pyorrhea or gum infection was observed in twenty-eight cases, or 41.8 per cent. Tooth defects, noted as dental caries, were observed in thirty-five cases, or 52.2 per cent. Tonsil infection, noted as hypertrophied, injected, and cryptic conditions, occurred in three cases, or 4.5 per cent. Actual, active infections about the mouth have not been stressed in the literature. Since this was one type of infection that we daily observed in these people, and since this was one type of infection that was actively present, we felt that it must be of some significance in producing arterial disease.

### Incidence of Past Diseases

Past diseases and foci of infections have been considered as important factors in producing arterial disease. In our series of cases the study of past diseases was not complete. We felt that incorrect answers were often received. The occurrence of past diseases in this type of person would be denied, through fear that such im-

TABLE 4.—INCIDENCE OF PAST DISEASES IN HYPERTENSIVE AND CONTROL GROUPS

| DISEASE | HYPERTENSIVE GROUP | CONTROL GROUP |
|---|---|---|
| Tonsillitis | 10 | 5 |
| Influenza | 9 | 7 |
| Smallpox | 5 | 6 |
| Appendicitis | 4 | 6 |
| Typhoid | 4 | 2 |
| Pneumonia | 4 | 4 |
| Diphtheria | 3 | 2 |
| Malaria | 3 | 2 |
| Alcoholism | 4 | 3 |
| Rheumatism | 4 | 2 |
| Hemorrhoids | 3 | 7 |
| Gonorrhea | 2 | 4 |
| Gallbladder | 2 | 1 |
| Aortitis | 1 | 0 |
| Scarlet fever | 1 | 3 |
| Blood poisoning | 1 | 1 |
| Poliomyelitis | 1 | 0 |
| Undulant fever | 1 | 2 |
| Syphilis | 1 | 3 |
| Arthritis | 1 | 3 |
| Osteomyelitis | 1 | 0 |
| Prostate | 1 | 0 |
| Boils | 0 | 2 |
| Renal colic | 0 | 1 |
| Chickenpox | 0 | 1 |
| Pleurisy | 0 | 1 |

parted information might interfere with employment. In the hypertensive group fifty-four, or 35.5 per cent., gave a history of past diseases. The control group showed that sixty, or 39.4 per cent., gave a positive history of past diseases. (See Table 4.)

Walker and O'Hare (12) studied comparative incidence of past infections in 400 patients with hypertension and in 400 hospital cases with normal pressure. They found the incidence of past infection to be about equal for the two groups. Apparently there is no experimental work that will support the idea that past diseases are important etiologic factors in hypertension. Stoll (13, p. 189) states that syphilis is one of the most common causes for hypertension. Ninety per cent. of his fifty cases of hypertension gave a positive Wassermann reaction. Up to the present time 179 of our cases, all of which were not hypertensive and all of which were not included in this study, have had Wassermann tests, and among these only eight positives were found (4.46 per cent.). Of this same number of cases, sixteen, or 8.93 per cent., gave a positive blood reaction indicative of undulant fever. Of the 527 cases studied in relation to blood pressure findings seventy had blood Wassermann determinations. Of these seventy cases, twenty-eight were found to have elevated blood pressures. Of these twenty-eight cases with blood pressure findings above normal, five, or 17.8 per cent., had positive blood Wassermann tests, and one, or 3.6 per cent., had undulant fever.

### Incidence of Impaired Vision

Impairment of vision is one of the signs of senility. From the time of birth the field of accommodation is progressively narrowed, from 14 diopters in the nursling to 7 at 30 years of age, 4 at 40 years, 2 at 51 years, and less than 1 diopter at 60 years. These changes constitute perhaps the best index of physiologic age recognizable clinically (1, p. 93).

Of the whole group of 304 cases 151, or 49.6 per cent., revealed impaired vision. The comparison of all the groups for each age period was interesting. The trend of impaired vision was always upwards. The whole group showed a gradually increasing impairment up to 45 to 49, from which period the increase was sudden, reaching 90.9 per cent. at the ages of 50 to 54. Of the 152 control cases fifty-eight, or 38.2 per cent., showed impaired vision. In the control group the incidence of impaired vision gradually increased to the age period 45 to 49; there then followed a sudden increase to 100 per cent. at the age period 50 to 54.

In the hypertensive group of 152 cases ninety-three, or 61.2 per cent., showed impaired vision. This group began earlier to show impaired vision. The increase was sudden up to 30 to 34 years of age, and from this age period on, it was rather gradual, reaching the peak at 55 to 59, at which period the percentage of impairment was 90.9 per cent. Of the 105 cases over 55 years of age, 86.7 per cent. had impaired vision; of the hypertensives in this group, 88.1 per cent.

### Incidence of Varicose Veins

The whole group of 304 cases showed varicose veins in 7.2 per cent. The incidence in the control group was 3.9 per cent., in the hypertensive group

10.5 per cent. The age period of their first occurrence was about the same for each group, at 40 to 49. In the hypertensives they began to occur more frequently from the age period 45 to 49. (See Fig. 3.) The frequency was greater in the cases over 55. Of the 105 cases over 55, 32.4 per cent. had varicosities and of the hypertensives 34.3 per cent.

The occurrence of varicose veins in the later periods of life was simultaneous with cardiac hypertrophy, dilatation, and myocardial weakness. This was significant. We could judge that circulatory weakness in regard

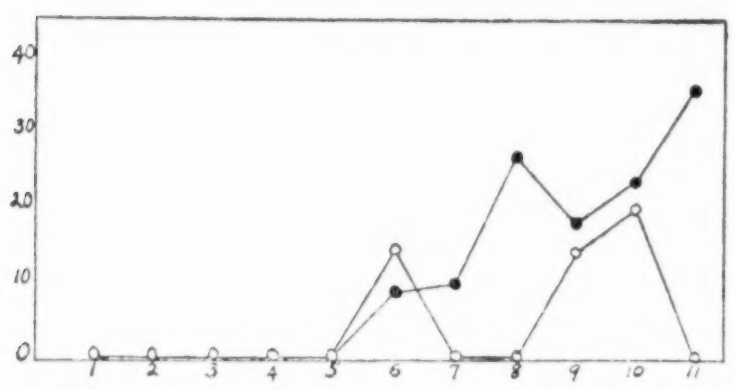


FIG. 3.—Percentage incidence of varicosities in control group of cases (solid line with circles) and in hypertensive group (solid line with solid circles).
1, 2, etc., as in Figure 1.

to the heart muscle had begun. From this alone we could see why varicose veins should be more common in the hypertensive than in the normal person. In the former group we have additional cause for varicose veins, that of myocardial weakness with resulting increased venous pressure. Varicose veins have a twofold importance: first, from the standpoint of trauma; and second, as indicative of myocardial degeneration.

The study of symptomatology was not so complete as we should have desired. As in giving the history of past diseases, the examinee would often deny symptoms for fear of losing his job. There were, however, a total of sixty-five cases of hypertension that showed symptoms and findings, as follows:

| *Symptoms* | *Incidence* |
|---|---|
| Nocturia | 8 |
| Blurring of vision | 5 |
| Headaches | 5 |
| Dyspnea | 3 |
| Dizziness | 2 |
| Impaired hearing | 2 |
| Substernal pain | 1 |
| Palpitation | 1 |

| *Findings* | *Incidence* |
|---|---|
| Systolic murmurs | 21 |
| Tremor of hands | 13 |
| Sluggish pupils | 10 |
| Glandular hypertrophy | 8 |
| Irregularities of heart | 5 |
| Edema | 2 |

## CONCLUSION

A series of 527 cases were studied in relation to the incidence of hypertension and concomitant findings. From this group 422 cases were selected and studied irrespective of findings.

Among the 422 cases hypertension was found to exist in 36 per cent. In a second series of 105 cases over 55 years of age the incidence of hypertension was 63.8 per cent. The percentage of cases of elevated blood pressure increased above the normal or control group from the age period 35 to 39.

Obesity occurred more frequently in the group with elevated blood pressure (28.4 per cent.) than in the whole group of cases (26.6 per cent.) or in the control group (25 per cent.).

Blood studies in relation to cholesterol determinations, syphilis, and undulant fever were made and reported. A high cholesterolemia of the

blood was found to exist in 70 per cent. of our cases with elevated blood pressure. Only seventy of the 527 cases studied had blood Wassermann determinations. Of these seventy, twenty-eight, or 40 per cent., had elevated blood pressure. Of the twenty-eight, five, or 17.8 per cent., had positive blood Wassermann tests.

The percentage of foreign born was greater in the cases of elevated blood pressure than in the control group.

The incidence of oral sepsis was greater in the hypertensive group (50 per cent.) than in the control group (35.5 per cent.).

A study was made of past diseases and of symptoms.

The incidence of impaired vision (61.2 per cent.) and varicosities (10.5 per cent.) was greater in the hypertensive group than in the control group (impaired vision 38.2 per cent.; varicosities 3.9 per cent.).

I wish to thank Mr. James Martin of the Bacteriology Department of the University of Nebraska College of Medicine for his co-operation in blood studies related to syphilis and undulant fever, and also Mr. C. R. Orchard, Employment Manager of Armour and Company of Omaha, who made this study possible.

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# INJURIES PRODUCED IN THE ORGANISM BY THE DISCHARGE FROM AN IMPULSE GENERATOR*

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IN a previous paper the authors have discussed the injuries produced in rats by contact with electric circuits, alternating or continuous, of 110 to 1,000 volts potential for different lengths of time, with the pathway of the current from the dorsal surface of the head to the tail (4). It was found that severe damage to the nerve cells was produced by currents at the higher voltages; at these potentials the nerve cell trauma was more severe after contact with the continuous than with the alternating circuit (6) (7). In another series of experiments the position of the electrodes, and hence the path of the current through the body, was subject to variation; the alternating or continuous circuit was maintained at 1,000 volts (5). The results demonstrated that recovery was more rapid and certain the less the direct pathway of the current traversed nervous structures. These observations support Urquhart's hypothesis (10) (11) that the electric current produces an inhibition of activity in the central nervous system. If the damage is not too severe, a restoration of function may occur, provided artificial respiration is maintained. In all these experiments the central nervous system was studied microscopically, in order to determine the extent of the injury. The rat was chosen as the experimental animal because its heart is little influenced by electric shocks, and ventricular fibrillation is not easily induced. This makes it possible to focus the attention upon the nervous system.

The impulse generator, also called surge or lightning generator, has recently assumed great importance in the electrical industry. Insulators on transmission lines not only must provide insulation for the circuit voltage but also must protect the line against lightning surges or strokes. For the purpose of testing the behavior of insulators under lightning conditions, the impulse generator has been developed. This produces a high voltage discharge that continues for only a few microseconds and is similar to a lightning stroke. When the discharge takes place the current rises very rapidly from zero to its greatest value, and then falls back to zero at a somewhat slower rate. The question has arisen as to whether there is danger to life associated with shocks of this character. In order to investigate the matter, the present series of experiments was undertaken.

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### Procedure

Rats were again used as experimental animals. Under the test conditions a current with a crest value of approximately 100 amperes at a maximum voltage of 200,000 volts passed through the animals. The duration of the surge was extremely brief, the entire discharge requiring only a little over four microseconds. The current rose from zero to its crest value in one-quarter of a microsecond and decreased to zero during the next four microseconds. The discharge resembled a bolt of lightning and was followed by a loud percussion. The portable surge generator used in these tests[1] produced a spark considerably over a foot in length which passed from the high voltage terminal to a ground plate.

Thirty-six experiments were conducted with the impulse generator operated with the discharge as described above. The rats were given ether before the experiments, until they were quite unconscious. In some of the tests the animals were laid on the ground plate and a clip was made fast to a given part of the body. This clip extended several inches above the surroundings and attracted the spark discharge to one particular location. In other tests the animal was suspended from the high voltage electrode in such a way that the discharge passed through a definite portion of the body. The damage produced was quite different in relation to the part of the body subjected to the discharge.

[1] This was kindly lent to us by the Westinghouse Electric and Manufacturing Company.

### Animals Laid on Ground Plate

Seven rats were laid flat upon the grounded copper plate. In three the clip was attached so that the discharge entered through the head, in three so that it entered through the center of the back at the level of the scapulae, and in one so that it entered through the lumbar region. All seven rats were active immediately following the shock. They breathed at once, so that no artificial respiration was required. The heart was not seriously injured. The only abnormalities occurred in two rats which received the contact through the upper thoracic region; these animals showed disturbances in equilibrium—one rolled to the left and the other ran in small circles to the left. It is possible that the discharge in these cases may have produced an irritation in the region of the medulla of the vestibular nerves or the vestibular nuclei. Both these rats were quite normal at the end of ten minutes.

In these tests where the animal lies flat on a plate, the current path through the body is very indefinite. The best that the experimenters can do is to direct the lightning flash to a given point on the body. It is evident from the results that little or no damage was produced by the surge under these conditions.

### Animals Suspended from Electrode

Four rats were so suspended by the tail from the high voltage electrode that the spark jumped from the head to the copper ground plate. The surge in this case traversed the entire body from tail to head. After the shock no heart beat could be felt; the

chest of one rat was opened at once and it was found that the heart was beating feebly. No ventricular fibrillation was induced. Although artificial respiration was used, none of the rats ever made any attempt to breathe. Following the shock, rhythmic tremors of the striated musculature were observed which were most marked in the hind legs. These experiments demonstrated that contact with the impulse generator was very dangerous when the electric pulse traversed the entire length of the body.

This was shown again when an animal was suspended from the occipital region and the current passed through the body to the tail. In this instance the spark passed from the tail to the ground. Only the posterior portion of the brain lay in the direct pathway of the current. The heart beat well and the rat made some attempts to breathe. Although artificial respiration was continued for some time, the animal died.

Four rats were suspended from the high voltage terminal by a clip attached to the back of the neck, the spark passing from the tail to the ground plate. As the skin is very freely movable in this region, the current probably entered the occiput and traveled to the tail. The brain stem, and hence the centers for respiration and areas of the brain controlling the heart, lay close to one electrode and in the path of the current. Here the discharge produced injury to the heart; immediately following the shock the heart beat could not be felt at all, but it became progressively stronger during the next few moments. Artificial respiration was used on all four of the rats and three of them took a few breaths, but they all died immediately.

Similarly, in the case of four rats the clip was fastened to the skin of the back in the midline between the scapulae so that the current path was from this region to the tail. The animals were so arranged in the circuit that the spark passed from the tail to the ground. Three of the rats recovered and one died at once. One breathed without aid; the other three were given artificial respiration and they all made some attempts to breathe. The heart beat was weak following the shock in the rat that died, but improved during the first half minute. Fibrillary tremors of the muscles were observed in all these experiments. The hind legs of two of the rats were very weak for an hour or two following the shock. The portion of the spinal cord controlling the hind legs may have received a concentration of the discharge.

Four rats were suspended from a clip attached to the skin in the dorsal midline of the midthoracic region so that the discharge flowed from this point to the tail, and as before, the spark passed from the tail to the ground plate. Three rats survived and one died after breathing spontaneously for a few minutes. In fact all four of the animals breathed immediately following the shock, and the heart beat well in all. There were marked tremors of the hind legs in each animal and the hind legs of one were weak for over an hour.

Four rats were now suspended from the electrode by the right foreleg, allowing the electric pulse to travel from the right foreleg to the tail, the spark jumping from the tail. One of

the animals breathed at once following the shock; the others were given artificial respiration. The heart beat well in each case. Two of the rats recovered and two died. One of the latter received two discharges from the impulse generator before the circuit could be cleared; the other made a few attempts to breathe but could not be saved.

In a similar way four rats were suspended by the left foreleg. One of these rats breathed at once but the other three died. Two of the latter made some attempts to breathe when artificial respiration was used. The heart beat well following the surge in three of the rats; in the other the heart beat was feeble for the first few seconds and then improved.

Four animals were suspended from the high voltage terminal by the dorsal surface of the head. A second wire electrode, attached by a clip to the midabdominal region, extended below their tails. The arrangement was such that the discharge passed through the animal, the spark jumping from the end of the wire to the ground plate. One rat breathed at once; two others started to breathe and stopped; and the fourth never breathed at all. The heart beat was detected in all this group and improved markedly in force during the first few moments following the injury. There were clonic tremors of the entire musculature, which were most marked in the hind legs.

## Discussion

These experiments show clearly that the damage to the organism is increased, the greater the portion of the body that is included in the path of the current. It is even more true that the damage is greater, the greater the amount of nervous structures traversed by the discharge. When the surge passed from the dorsum of the head to the tail throughout the entire length of the body, none of the animals survived the shock. The same was true with the current traversing the body from the occipital region to the tail. When the circuit did not include the head, the current path being from the upper or the mid-thoracic region to the tail, many of the rats recovered. If the pathway of the pulse was from a foreleg to the tail, the animals had about a 50 per cent. chance of survival.

Circuits involving even less of the body were less dangerous. In cases where a single spark jumped to the body of a rat lying flat on the ground electrode the animal was active at once, whether the surge entered through the head, or through the thoracic or the lumbar region. It might be permissible to conclude from this that man is safest in a severe electric storm if he lies on the ground.

The chests of the rats were usually well expanded following the shock. In previous papers the difficulties of giving any really adequate artificial respiration in the case of such small animals have been discussed.

The heart of the rat is little influenced by electric shocks. In previous experiments with alternating and continuous voltages there were very few instances in which it was thought that the heart was injured. This is certainly not true of the present group. Even here no ventricular fibrillation was produced. The force of the heart beat was markedly influenced

in a number of cases. When the current traversed the whole length of the body no heart beat could be detected. The chest was opened in the case of one rat and it was found that the heart was beating at a normal rhythm. In many other experiments it was observed that the force of the heart beat was very slight immediately following the injury but improved greatly during the next few seconds.

A number of phenomena were observed which are related to damage of the nervous system. The hind legs were weak for a short time following the shock in a few animals in which one contact was close to the lumbar portion of the cord and the discharge traversed this region. In every case this weakness persisted less than an hour. Several rats showed signs of vestibular irritation lasting a few minutes. During this time they walked or rolled to one side. Tremors of the musculature were seen in almost every case; these tremors were most severe in that portion of the body whose nervous control lay most directly in the path of the current.

It is very interesting to speculate concerning the nature of the damage produced in the cells by an electric surge of this type, and a microscopic study of the material is planned. In the case of injuries produced by alternating or continuous circuits, particularly at high voltages, there is considerable heat developed in the body. This is greatest at the site of the electrodes where the contact resistance is high. In the earlier experiments the question has arisen as to how much of the damage found in the nerve cells was due to heating. In the present series the period of the discharge was so brief that there was no indication of any rise in body temperature. The discharge of a surge generator may be made to split a stick of wood just as lightning shatters a tree. It is conceivable that an electric blow of this character may disrupt many of the cells of the body.

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## BOOK REVIEWS

ACCIDENTAL INJURIES. The Medico-Legal Aspects of Workmen's Compensation and Public Liability. By *Henry H. Kessler*, A.B., M.D., F.A.C.S., F.A.P.H.A., Medical Director, New Jersey Rehabilitation Clinic; Formerly Medical Advisor, New Jersey Workmen's Compensation Bureau; Chairman of the Committee on Standard Practices in Compensation for Occupational Disease, and Chairman of the Subcommittee on Standards of Diagnosis and Prognosis of Lead Poisoning, American Public Health Association; Member of the Society of Medical Jurisprudence; Medical Director of the Occupational Disease Clinic in the New Jersey Department of Labor. Cloth. Pp. xx, 718 with index and illustrations. Philadelphia: Lea & Febiger, 1931.

This very complete work is quite unique. It discusses accidental injuries not from the point of view of etiology, pathology, diagnosis, and treatment but from the angle of the amount of disability they cause. It is largely devoted to discussing the importance of properly evaluating the temporary and the permanent effects of an accident upon the earning power of the injured person.

The workmen's compensation laws are briefly but carefully reviewed, and special attention is given to their medical aspects.

The pathology of trauma is considered under the headings of biomechanics and sequelae, while an entire chapter is devoted to a discussion of the end-results of injuries.

There is an interesting section upon the general principles underlying disability, in which the difference between temporary and permanent disability is defined and a standard basis of evaluation is demonstrated.

Following these more general topics the author specifically applies the principles he has developed to injuries of the different regions of the body. Traumatic neuroses, occupational disease, and rehabilitation are given careful consideration.

This book is particularly valuable as a reference work. Many types of injury infrequently seen are discussed as carefully as those which are more common, so that considerable help can be obtained in evaluating not only the usual disabilities, but also those caused by unusual and complicated accidents.

The author has developed a plan of examination of the injured part and an estimation of its disability by measurement, which is thoughtful and which should be more accurate than the methods at present in use.

The book is well illustrated and each chapter is followed by a list of references. In a number of cases court decisions are quoted.

The surgeon who does traumatic work or who sees many industrial accident cases will find this work valuable, especially if he is frequently called upon to determine the amount of disability resulting from injuries.—*W. Irving Clark.*

HEATING AND VENTILATION. By *John R. Allen*, Late Director of Research Laboratory of American Society of Heating and Ventilating Engineers; Formerly Dean of Engineering and Architecture, University of Minnesota; Past President American Society of Heating and Ventilating Engineers; and *James H. Walker*, Superintendent of Central Heating, The

Detroit Edison Company; Member American Society of Heating and Ventilating Engineers; Member American Society of Mechanical Engineers; Past President National District Heating Association. With a chapter on Hot-Water Heating Systems by F. E. Giesecke, Ph.D., Director, Texas Engineering Experiment Station, Agricultural and Mechanical College of Texas. Third Edition. Cloth. Pp. xiii, 426 with diagrams, appendix, and index. New York and London: McGraw-Hill Book Co., Inc., 1931.

This excellent book, originally published in 1918 and reprinted in 1922, has now been completely revised to include the recent phenomenal advances in the science and art of ventilation and air conditioning.

All phases of heating, ventilation, and air conditioning are discussed in a clear and concise manner. Old chapters have been enlarged and much additional information has been added on hot water heating systems (by Professor F. E. Giesecke), cleaning, artificial cooling of air, and industrial air conditioning.

The scope of the work is broad enough to serve as an up-to-date manual of design for the practising engineer, as well as a textbook for engineering schools and the individual student. Most of the chapters contain practical problems, some of which are solved in the text. Answers to the unsolved problems may be obtained by writing to Mr. Walker.—*C. P. Yaglou.*